COMPUTER SIMULATION AS AN AUDITING TOOL

Willis Eugene Lowery

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA 93940

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

COMPUTER SIMULATION AS AN AUDITING TOOL

by

Willis Eugene Lowery
Edmond Lamar Allen

June 1974

Thesis Advisor: D. C. Burns

Approved for public release; distribution unlimited.

T161643

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS
BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
COMPUTER SIMULATION
AS AN AUDITING TOOL

5. TYPE OF REPORT & PERIOD COVERED
Master's Thesis;
June 1974

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Willis Eugene Lowery
Edmond Lamar Allen

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93940

12. REPORT DATE
June 1974

13. NUMBER OF PAGES
70

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
Naval Postgraduate School
Monterey, California 93940

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Auditing
Computer Simulation
Internal Control
Reliability

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This thesis describes the application of computer simulation techniques to auditing a military payroll system. After review of the system, a simulation model was constructed to assist the auditor during the preliminary evaluation in establishing threshold limits for internal control compliance. The model describes potential errors and irregularities that could occur, their probability of occurrence, and the internal

20. Abstract.

controls that should prevent or detect those errors. Given the probability of various errors and the internal control compliance rates, the model generates the expected value and standard deviation of the error in the system output data. This output data serves as an objective basis for judging the adequacy of the system.

Computer Simulation

as an Auditing Tool

by

Willis Eugene Lowery
Commander, United States Navy
B.S., University of Rochester, 1955

and

Edmond Lamar Allen
Lieutenant Commander, United Staes Navy
B.S., University of Washington, 1961

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
June 1974

Thesis
L867
c.1

DUDLEY KNOX LIBRARY
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA 93940

ABSTRACT

This thesis describes the application of computer simulation techniques to auditing a military payroll system. After review of the system, a simulation model was constructed to assist the auditor during the preliminary evaluation in establishing threshold limits for internal control compliance. The model describes potential errors and irregularities that could occur, their probability of occurrence, and the internal controls that should prevent or detect those errors. Given the probability of various errors and the internal control compliance rates, the model generates the expected value and standard deviation of the error in the system output data. This output data serves as an objective basis for judging the adequacy of the system.

TABLE OF CONTENTS

I. INTRODUCTION 9
- A. GENERAL 9
- B. PRELIMINARY EVALUATION PROBLEMS 10
- C. PURPOSE 11
- D. METHODOLOGY 12

II. THE PAYROLL SYSTEM 15
- A. DESCRIPTION 15
- B. POTENTIAL ERRORS AND IRREGULARITIES 15
  - 1. Input Document Errors 16
  - 2. Record Tampering Error 16
  - 3. Calculation Error 16
  - 4. Record Inclusion/Exclusion Error 17
  - 5. Clerical Error 17
  - 6. Defalcation 18
- C. PERTINENT ACCOUNTING CONTROLS 18
  - 1. Input Document Controls 18
  - 2. Pay Record Tampering Controls 19
  - 3. Payroll Inclusion/Exclusion Controls 19
  - 4. Calculation Controls 20
  - 5. Clerical Controls 20
  - 6. Defalcation Controls 20
  - 7. External Control 21

III. THE PAYROLL MODEL 22
- A. LOGIC 22
- B. OPERATING CHARACTERISTICS AND OUTPUT 24
  - 1. Random Numbers..24
  - 2. Verification Of Program..25
  - 3. Convergence Of Output..25
- C. PROGRAMMING 26

IV. RESULTS OF SIMULATION 28
- A. BASIC RUN 28
- B. PESSIMISTIC CASE 28

C. SENSITIVITY OF MODEL 29
D. RANGED INTERNAL CONTROL COMPLIANCE RATES.......34
V. SUMMARY AND COMMENTS 36
APPENDIX A Description Of The System 37
APPENDIX B Identification Of Errors And Irregularities.41
APPENDIX C Description Of Simulation Model 46
SAMPLE COMPUTER OUTPUT 59
COMPUTER PROGRAM 60
LIST OF REFERENCES......................................69
INITIAL DISTRIBUTION LIST...............................70

LIST OF FIGURES

1. Payroll Department Document Flow.................... 14
2. Payroll Simulation Model Flowchart................. 23
3. Mean Error vs. Number Of Iterations................ 26
4. Mean Error vs. Probability Of Input Document Error.............................. 31
5. Mean Error vs. Probability Of Record Tampering Error 31
6. Mean Error vs. Probability Of Record Tampering Control.............................. 32
7. Mean Error vs. Probability Of Defalcation.......... 32
8. Mean Error vs. Probability Of Defalcation Control.. 33
9. Mean Error vs. Probability Of Check Return......... 33
10. Mean Error vs. Control Compliance Rates............ 34
11. Standard Deviation vs. Control Compliance Rates.... 35
12. Program Logic Flowchart........................... 50

ACKNOWLEDGEMENTS

The guidance, assistance, and patience of Professor David C. Burns, Department of Operations Research and Administrative Sciences, Naval Postgraduate School, is gratefully acknowledged. This thesis could not have been successfully completed without his interest, knowledge, and experience in the techniques of computer simulation applied to auditing problems. The assistance of Lt. Col. Russell E. Jamison, USMC, Department of Operations Research and Administrative Sciences, Naval Postgraduate School is gratefully acknowledged. His review, constructive comments, and recommendations contributed materially to this thesis. Appreciation is given for the assistance of the Naval Postgraduate School computer center personnel, Edwin Donnellan, Kristina Butler and Mannas Anderson. Last but not least, a note of thanks to the wives of the authors for their assistance in spelling, punctuating, proof reading, and understanding.

I. INTRODUCTION

A. GENERAL

Section 320 of Statement on Auditing Standards No. 1 contains the following outline of an approach for evaluating internal control:

> A conceptually logical approach to the auditor's evaluation of accounting control, which focuses directly on the purpose of preventing or detecting material errors and irregularities in financial statements, is to apply the following steps in considering each significant class of transactions and related assets involved in the audit:
>
> a. Consider the types of errors and irregularities that could occur.
>
> b. Determine the accounting control procedures that should prevent or detect such errors and irregularities.
>
> c. Determine whether the necessary procedures are prescribed and are being followed satisfactorily.
>
> d. Evaluate any weaknesses (i.e., types of potential errors and irregularities not covered by existing control procedures) to determine their effect on (1) the nature, timing, or extent of auditing procedures to be applied and (2) suggestions to be made to the client.[1]

Although this outline is tailored to the specific requirements of a final evaluation of internal controls (i.e., the evaluation performed subsequent to compliance

---

[1] Committee on Auditing Procedures, Statement of Auditing Standards #1, American Institute of Certified Public Accountants, Inc., 1973, p. 31.

testing), paragraph 54 of section 320 recommends that the same basic approach be employed for a "preliminary" evaluation of internal controls.

Preliminary evaluations are normally performed immediately after prescribed internal controls are reviewed but before compliance tests are designed and performed. The major purposes of a preliminary evaluation are threefold:

1. To identify obvious strengths and weaknesses in prescribed accounting controls which could have a bearing on the audit program ultimately applied.

2. To develop a tentative audit strategy of compliance tests and substantive procedures early in the audit.

3. To establish upper precision limits (i.e., tolerable error rates) for compliance tests compatible with this tentative audit program.

B. PRELIMINARY EVALUATION PROBLEMS

Implementation difficulties often arise when the section 320 evaluation approach is employed to perform an evaluation of an extensive system of internal controls. Many systems requiring a total system approach involve the processing of several different classes of transactions. Such systems are often composed of a multitude of interrelated internal controls. Under these circumstances, it is often difficult to assess the potential financial statement impact of each control, and even more difficult to assess the potential joint impact of all controls. When internal controls operate in either a joint or feedback fashion, as they often do in inventory or payroll systems, conceptual evaluation of the system can become hopelessly complex. As a result, several accounting researchers have set out to develop analytical methods to assist the auditor in evaluating complex internal control systems. Thus far, the following three methods have been proposed:

1. A matrix algebra approach proposed by Professors Yu

and Neter.[2]

2. A statistical modeling approach based on the concepts of reliability engineering proposed by Professor Cushing.[3]

3. A Monte Carlo computer simulation technique proposed by Professor Burns.[4]

To date none of these approaches has been applied to evaluate an actual system.

C. PURPOSE

This thesis illustrates a practical application of the computer simulation evaluation method propcsed by Burns. It describes how computer simulation was employed to perform a joint preliminary evaluation of all pertinent accounting controls related to a real world payroll system.

The approach proposed by Professors Yu and Neter was not selected for this thesis because: (a) their approach fails to consider the detailed characteristics of any errors considered possible in the circumstances and (b) it fails to consider the potential dollar impact of possible errors and irregularities on the financial accounts.

Professor Cushing's approach was not selected because: (a) it does not distinguish between an error free system and a system plagued by offsetting errors and (b) it is not well suited to evaluations of systems which encompass several different types of errors.

---

[2] Yu, S. and Neter, J., A Stochastic Model of the Internal Control System, Faculty Working Papers, College of Commerce and Business Administration, University of Illinois, Urbana-Champaign, 17 April, 1973.

[3] Cushing, B. E. "A Mathematical Approach to the Analysis and Design of Internal Control Systems," Accounting Review, v. XLIX, No. 1, p. 24-41, January 1974.

[4] Burns, D. C., Computer Simulation of Internal Controls, paper presented at Midwest Regional Conference of American Institute for Decision Sciences, 5th, Minneapolis, Minnesota, 10-11 May 1974.

The Monte Carlo technique was chosen because it can be: (a) Adapted to a wide variety of actual system structures. (b) Used to represent most of the probabilistic error processes which are found in real world systems. (c) Adapted to represent complex accounting control/error interrelationships and feedback processes.

D. METHODOLOGY

The Monte Carlo approach was applied to an actual payroll system which pays approximately 1700 personnel twice a month. An internal control review was performed to identify all pertinent prescribed controls. Controls were observed that do not leave an audit trail. A document flowchart of this payroll system is presented as figure 1.

A preliminary evaluation of the payroll system was then performed using computer simulation as an audit tool. The four step evaluation approach quoted previously was employed as follows:

1. Consideration was given to the various types of errors and irregularities which might occur. The writers were of the opinion that six basic types of errors were possible. These potential errors were identified and quantitatively defined so that they could be incorporated in the simulation program.

2. Consideration was given to the accounting control procedures that could prevent or detect the six types of errors believed possible.

3. Pertinent prescribed accounting controls were identified pending further clarification by simulation testing. These controls were incorporated in the design of the simulation model.

4. A computer simulation model of the six error processes and pertinent prescribed controls was constructed. This model was used to enumerate the total dollar amount of undetected error which might be generated by the system (as

conceptualized by the writers) over one pay period (one half month). The model was tested using various error rates and levels of internal control effectiveness.

SIMPLIFIED DOCUMENT FLOW

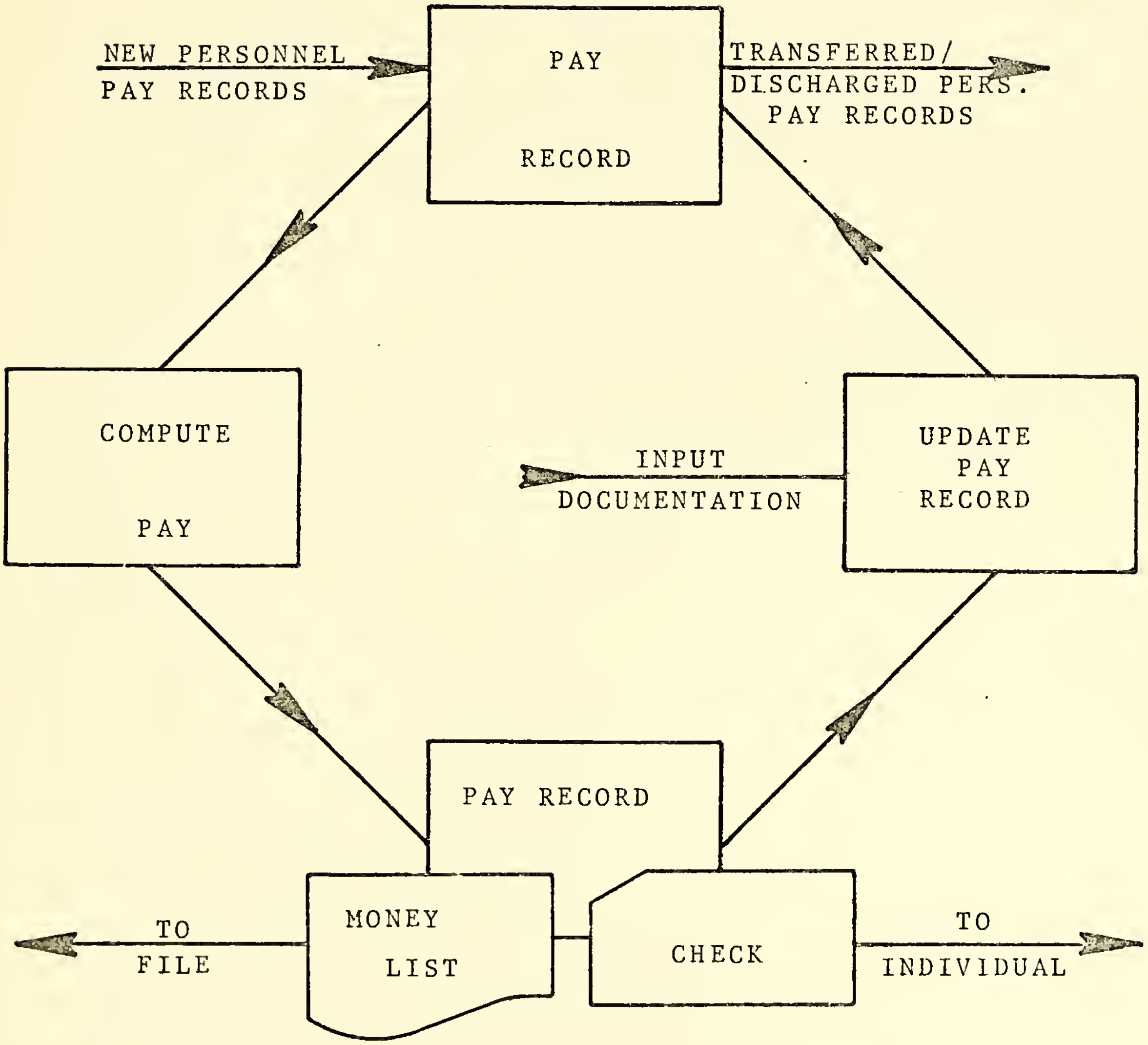

NEW PERSONNEL
PAY RECORDS
PAY
RECORD
TRANSFERRED/
DISCHARGED PERS.
PAY RECORDS
COMPUTE
PAY
INPUT
DOCUMENTATION
UPDATE
PAY
RECORD
PAY RECORD
TO
FILE
MONEY
LIST
CHECK
TO
INDIVIDUAL

FIGURE 1

II. THE PAYROLL SYSTEM

A. DESCRIPTION

The payroll system selected is representative of many found in the business community. Each individual's authorized rate of pay, withholding information, and other data concerning payroll deductions are maintained on a permanent employee "pay record" card. Changes in this information are received with appropriate authorization from the personnel office. Prior to each payday, these changes are entered on the pay record as required and each employee's pay for the period is calculated. As each payroll is prepared, the amount paid is entered simultaneously on the pay record, the payroll check and a "money list" (listing by name of each employee and his authorized pay). After the payroll checks are prepared, they are machine signed and either distributed by authorized personnel or mailed directly to the employee's bank. A detailed narrative description of the payroll system appears in Appendix A.

B. POTENTIAL ERRORS AND IRREGULARITIES

All errors believed possible in the case of the payroll system were grouped into six major categories. Each error category was treated as a separate stochastic process of the model. A detailed description of these errors and irregularities appears in Appendix B.

An impression was formulated as to occurrence rate and dollar magnitude of each category of error. To provide the maximum credible quantitative system error, pessimistic values were assigned to these occurrence rates and error magnitudes. The six major categories of errors and their assigned statistical properties are as follows:

1. Input Document Errors

Payroll record change documents received by the payroll department from the personnel department could contain monetary errors, non-monetary errors, or both. These errors range from lack of authorizing signature and incorrect social security numbers to erroneous pay rates and tax exemptions. It was the writers' impression that these types of errors could lead to monetary errors in no more than 15 out of every 100 documents processed. It was the writers' further impression that the dollar magnitude of such errors might be normally distributed. It was decided that the mean dollar value of such errors would not exceed $50.00 and that the standard deviation would probably not exceed $50.00.

2. Record Tampering Error

Any changes to a pay record which are not supported by documentation from the personnel department are considered here to be "pay record tampering error". In the case of the subject system, this type of error could arise in two ways. The employee could gain either direct or indirect access (i.e., by collusion) to his pay record and alter it to reflect a higher pay schedule. A payroll clerk or payroll supervisor could alter his own pay record in a similar fashion. A pessimistic occurrence rate of 5 in 1000 records processed was assigned to this type of error. A high occurrence rate was assigned to this error process in order to reflect the undesirable qualitative aspects of this type of intentional error in the model. Since an abnormally high increase in pay would probably be detected by the system, a mean value of $200.00 and a standard deviation of $50.00 was defined as the magnitude of this type error.

3. Calculation Error

Prior to each payday, a payroll clerk calculates the

amount due each employee. The clerk uses the information on the pay record for this calculation. The process involves determination of the gross pay due the employee. Then adjustments are made to this gross pay figure for FICA, income taxes, and other deductions either required by law or authorized by the employee. During this process, various tables are consulted and several numeric calculations are performed. At any point, the clerk could make a computation error. An occurrence rate of 10 errors per hundred records was defined for this type of error. The expected dollar value of this error was set at 5 percent of the base pay.

4. Record Inclusion/Exclusion Error

Since there is a turnover in employees between paydays, there exists the possibility that a pay record could be included or excluded incorrectly from the payroll. Errors of this type would probably result from a breakdown of the internal communication system within the organization or through an intentional defalcation. If new employee pay records are not delivered to the payroll department in a timely manner, the employee will not be paid on time.

Upon leaving, an employee is paid and his pay record is removed from the system. If, however, an employee neglected to collect his terminating pay, his pay record could remain in the payroll system for some time. It was the investigators' impression that this type of error could occur one time in 100 and that the ratio of errors of exclusion to errors of inclusion might be 3 to 1. The dollar magnitude of these errors depended upon the specific payroll record involved. Payroll record data was fed to the model as an external input.

5. Clerical Error

An NCR class 33 accounting machine is used to print simultaneously the dollar value on the pay record, money list, and the check. During the keying process, the machine

operator could inadvertantly transpose two digits. An occurrence rate of 10 out of each 100 documents processed was assigned to this type of error. The error was defined to be normally distributed with a mean of $0.00 and a standard deviation of $100.00.

6. Defalcation

Defalcations could occur in the payroll department. Payroll clerks could introduce bogus pay records intc the system and cash the checks drawn to those bogus pay records or simply steal blank checks and process them through the check signing machine or forge the disbursing officer's signature. An occurrence rate of 1 out of 1000 records processed was assigned to this type of error. It was further determined that the magnitude of this error might be normally distributed with an expected value of $2000.00 and a standard deviation of $1000.00. Negative defalcations were not allowed. Again, a high occurrence rate was assigned to this type of error in order to reflect the undesirable qualitative aspects of an intentional defalcation.

C. PERTINENT ACCOUNTING CONTROLS

Integral to the payroll system are a set of internal controls designed to either prevent or detect and correct the errors discussed in the previous section. Some of these controls leave an objective audit trail while others are either of a safeguard nature or of a review nature which consequently leave no such audit trail. Examination of the system led to the identification of seven discrete groups of pertinent controls. Each group was treated as a single control for the purpose of the model. These controls are as follows:

1. Input Document Controls

As each payroll change document is received from the personnel department it is reviewed for reasonableness and authority and edited for obvious clerical errors. This review process should detect and correct most obvious administrative and clerical errors committed within the personnel department. However, a document authorizing the modification of the wrong pay record would probably not be detected by this control. Also, it is unlikely that the control would detect a fraudulent change notice which contained a valid authorizing signature. It was the investigators' impression that these controls might be 80 percent effective in detecting input document errors.

2. Pay Record Tampering Controls

These controls leave no objective audit trail. However, they do provide a series of safeguards which are designed to discourage and prevent tampering with pay records. These safeguards consist of various policies and operating procedures designed to restrict access to the pay records. Positive control is maintained over both active pay records and blank pay record cards. Clerks are rotated in their duties to prevent the permanent introduction of a bogus record.

No violations of these safeguards were noted during the physical observation of the payroll system. However, management's ability to detect such violations appeared quite weak. It was the writers' opinion that these controls might be only 50 percent effective in preventing or detecting payroll tampering errors if such tampering did occur.

3. Payroll Inclusion/Exclusion Controls

An employee, upon leaving the organization, is given a check-out form which is to be initialed by various departmental personnel. When this form is presented by the employee to the payroll department, the payroll clerk

initials the form and removes the pay record from the system. Periodically a listing of all employees is sent to the payroll department to provide verification of the pay records. To a great extent these controls rely upon the individual employee's desire to receive severance pay. It was the writers' impression that this control might be 95 percent effective in preventing improper payroll inclusion or exclusion errors.

4. Calculation Controls

The amount due the employee is calculated and then entered in the pay record as a penciled marginal note. The payroll clerk compares the most recent marginal note to previous payments in order to detect any significant changes in pay due the employee. If there is a significant change, the clerk is supposed to satisfy himself as to the reason for the difference. Clerks are rotated periodically to increase the effectiveness of this control. In the opinion of the investigators, it seemed likely that this control would be at least 95 percent effective in detecting clerical payroll calculation errors.

5. Clerical Controls

Adding machine tapes of the individual checks, the money list, and pay record entries are prepared by a payroll clerk. These tapes are verified for accuracy by two clerks. It was the writers' impression that this control should detect and correct 95 percent of the errors resulting from erroneous keying on the NCR machine.

6. Defalcation Controls

These controls consist of a series of safeguards designed to discourage or prevent a payroll defalcation. Standard procedures are used such as insuring annual vacations of all clerks, rotation of the various duties among several clerks, and periodic transfer of personnel to

other payroll departments. Every six months the pay records are closed out and sent to a central office for auditing and in addition, each year there is a detailed local audit of the system conducted. Safeguards in the system would, in general, prevent the systematic defalcation of relatively small amounts over a long period of time. However, there does exist the possibility of a material one time defalcation by creating a high dollar value bogus check. The impression of the investigators was that the efficiency of this control might be as low as 80 percent in preventing such a defalcation.

7. External Control

Most employees' perceptions of the payroll system lead them to the belief that an over payment of salary will ultimately be detected and withheld from their future pay. This results in an external control on the system. For purposes of the simulation model, it was assumed that 85 percent of the employees are honest if the error results in an over payment and 100 percent honest if the error results in under payment. Of the 15 percent who might not return an over payment, it was further assumed that as the magnitude of the over payment increased the probability of check return also increased. A maximum acceptable overpayment was defined to have a mean of $0.00 and a standard deviation of $40.00.

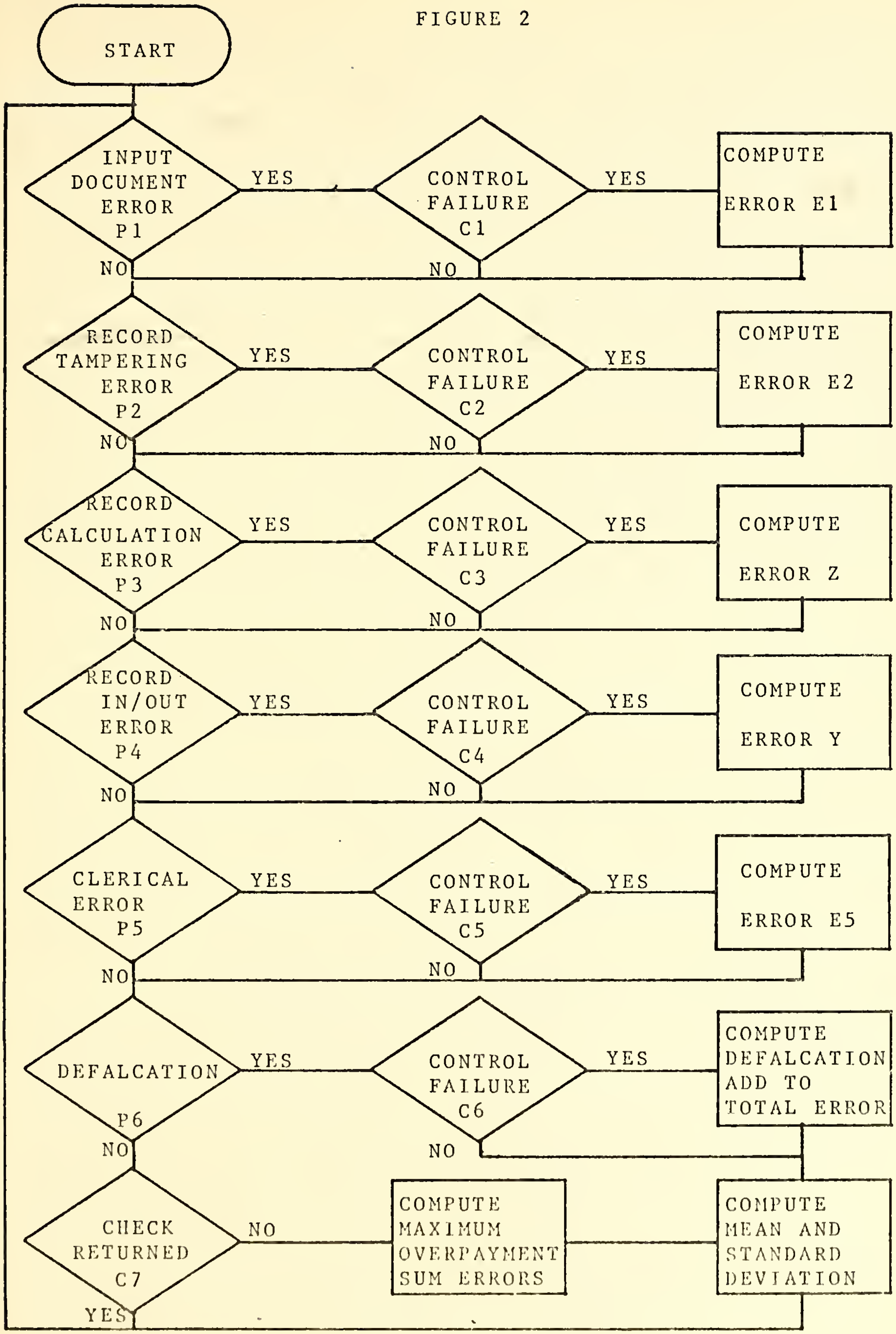
III. THE PAYROLL MODEL

A. LOGIC

The payroll simulation program is written in Fortran IV. The basic program logic is flowcharted in Figure 2. As Figure 2 illustrates, the basic program logic is divided into seven stages. The first six stages correspond to separate payroll processing steps where an error is believed possible. The seventh stage represents the external control process discussed earlier. The program stages are organized to follow the logical processing flow of the payroll system. Internal control processes are incorporated in the program at their proper positions. The program is designed to proceed through all seven stages one payroll record at a time.

At each program stage, the question is asked, "did an error occur in performing this operation on this payroll record?" The program answers this question probabilistically by selecting a psuedo-random number from the random number generator and comparing this random number to a previously defined error occurrence rate. If this random number comparison does not trigger the occurrence of the error, the simulation program proceeds to the next stage. If the error is triggered, the program branches to a relevant control process to further determine whether or not the prescribed control will detect and correct (or prevent the occurrence of) the error in question. Internal control failures are triggered probabilistically by a random number process similar to that described above for the error process. If the control does not fail, the program branches to the next stage. If the control fails, the program calculates the dollar error based on a predefined rule. The dollar amounts of all undetected errors are accumulated by

FIGURE 2


START
INPUT DOCUMENT ERROR P1
YES
CONTROL FAILURE C1
YES
COMPUTE ERROR E1
NO
NO
RECORD TAMPERING ERROR P2
YES
CONTROL FAILURE C2
YES
COMPUTE ERROR E2
NO
NO
RECORD CALCULATION ERROR P3
YES
CONTROL FAILURE C3
YES
COMPUTE ERROR Z
NO
NO
RECORD IN/OUT ERROR P4
YES
CONTROL FAILURE C4
YES
COMPUTE ERROR Y
NO
NO
CLERICAL ERROR P5
YES
CONTROL FAILURE C5
YES
COMPUTE ERROR E5
NO
NO
DEFALCATION P6
YES
CONTROL FAILURE C6
YES
COMPUTE DEFALCATION ADD TO TOTAL ERROR
NO
NO
CHECK RETURNED C7
NO
COMPUTE MAXIMUM OVERPAYMENT SUM ERRORS
COMPUTE MEAN AND STANDARD DEVIATION
YES

the program.

After passing through the program, 1 is added to a counter. The value in the counter is compared with a predefined number (in this case 1700, the number of employees included in the payroll). If the counter does not equal the total number of payrcll records to be processed, the cycle is repeated until the number of passes through the program is equal to the number of checks processed for a payday. The sum of all the errors, which have been accumulated, represents the total error present on the first payday. The process is repeated and the total error for the second payday results. The process is repeated again. The result is a string of values each representing a potential total dollar amount of error which might occur in processing 1700 payroll records. At any point, the mean and standard deviation of the string of error values can be calculated.

B. OPERATING CHARACTERISTICS AND OUTPUT

1. Random Numbers

The simulation program calls a library sub-routine which generates uniformly distributed psuedo-random numbers. The sequence of random numbers generated is uniquely determined by a user specified "seed" number. Once the "seed" number is specified, the random number sequence is determined and can be duplicated during subsequent computer runs. Twc types of random number sequences were used:

a. Uniformly distributed random numbers with values beween 0 and 1 were used with the probabilities to determine if a specific branch was taken. For example, assume a probability of .6 was assigned to an event. A random number X would be called. If the random number X were greater than .6, then the event did not occur and the branch was not taken.

b. Normally distributed random numbers about 0 with a standard deviation of 1 (standard deviate) were used to

compute most monetary errors. For example, a normally distributed random number X is called. The dollar error is then calculated by multiplying X by S (sample standard deviation) and adding the result to U (mean dollar error).

2. Verification Of Program

The logic of the program was tested using techniques suggested by Conway, Johnson, and Maxwell. The model was "broken down into a set of elements for which operating rules can be given."[5] Each element was subjected to a series of tests to determine if the element was behaving in accordance with the writers' wishes. These tests involved selection of input parameters and the verification of output by manual offline methods. For example, the document input error/control processes (P1&C1) were tested as an element (see Figure 2 page 23). The remaining elements (P2/C2 through P6/C6 and C7) were blocked by setting P2 through P6 and C7 to 0.0. Input parameters were assigned to the P1/C1 element and the output verified using a hand calculator. The P1/C1 element was blocked by setting P1 at 0.0. The P2/C2 element was checked. This procedure was repeated until all elements were verified.

3. Convergence of Output

Seventeen hundred payroll records were processed to determine the dollar value error for a single payday (one model iteration). A moving average dollar error and standard deviation was generated for 2,000 iterations. Figure 3 is a display of the mean value as a function of the number of iterations. As the graph shows, the change in the mean dollar value becomes very small after three hundred iterations. Any changes after that point are immaterial

---

[5] Conway, R. W., Johnson, B. M., and Maxwell, W. L., "Some Problems of Digital System Simulation", Management Science Journal, v.6, p 94, October 1959.

from an audit standpoint (i.e., they would not cause an auditor to change his decision). For the purpose of subsequent analysis, the values quoted for the mean and standard deviation are based on 500 iterations.

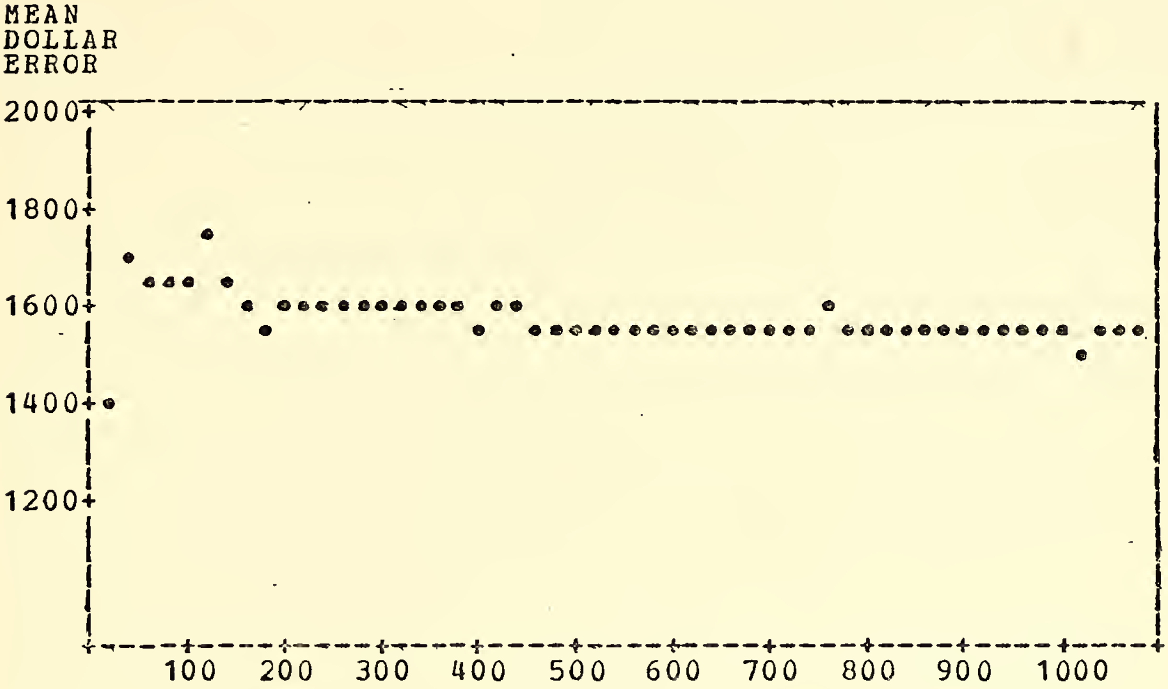


FIGURE 3

C. PROGRAMMING

The authors had no computer programming experience prior tc constructing the payroll simulation model. The preparation for the effort consisted of approximately five hours study of a book on Fortran IV programming. More time was spent attempting to model the payroll system and develop a logical series of events and steps than was spent in actually writing the program. Three hours were spent coding the logic in Fortran IV to convert the model into a computer program. The program was then run on an IBM System 360, Model 67 computer. Approximately 12 hours were spent correcting keypunch and logical errors in the program. The model was tested using simple data and the results were verified by offline procedures. Once the simulation model

was verified to be operating properly, much time was spent sensitivity testing the model. The analysis of the sensitivity test results contributed to the writers' insight concerning the impact of the combined effect of the error and control processes. On many occasions, the model generated results that were counter-intuitive but, on further reflection and study, these results became eminently logical and reasonable.

IV. RESULTS OF THE SIMULATION

A. BASIC RUN

The values of the input parameters for the basic run were as follows:

TYPE ERRORS	ERROR OCCURRENCE RATE	INTERNAL CONTROL EFFECTIVENESS	MEAN ERROR VALUE	STANDARD DEVIATION OF ERROR
Input Document	15 in 100	80%	$50.00	$50.00
Record Tamp.	5 in 1000	50%	$200.00	$50.00
Calculation	10 in 100	95%		
Record In/Out	10 in 1000	95%	1 to 3*	
Clerical	10 in 100	95%	$0.00	$100.00
Defalcation	1 in 1000	80%	$2000.00	$1000.00
Check Return		85%	$0.00	$40.00

* ratio of extraneous record inclusion.

The values obtained from the model using the above parameters were $1560.00 for the total mean net dollar error and $1474.00 for the standard deviation of the net error.

It is important at this point to remember that the model is not a model of the real ststem but only a model of the auditor's impressions concerning the pertinent error and control processes of the system. Thus, the parameters used to run the model are assumptions made by the writers based on their impressions of the system. This thesis illustrates how these impressions can be enumerated over time in an objective manner. The question of how these impressions are formulated is beyond the scope of this thesis.

B. PESSIMISTIC CASE

Most auditors would be interested in knowing what the

net dollar error might be under the most pessimistic circumstances. The writers tested this hypothesis using the following parameters in the model:

TYPE ERROR	INTERNAL CONTROL EFFECTIVENESS	ERROR OCCURRENCE RATE
Input Document	80%	2 in 10
Record Tampering	50%	1 in 10
Calculation	90%	1 in 10
Record In/Out	90%	1 in 10
Clerical	90%	1 in 10
Defalcation	80%	1 in 10
Check Return	80%	---

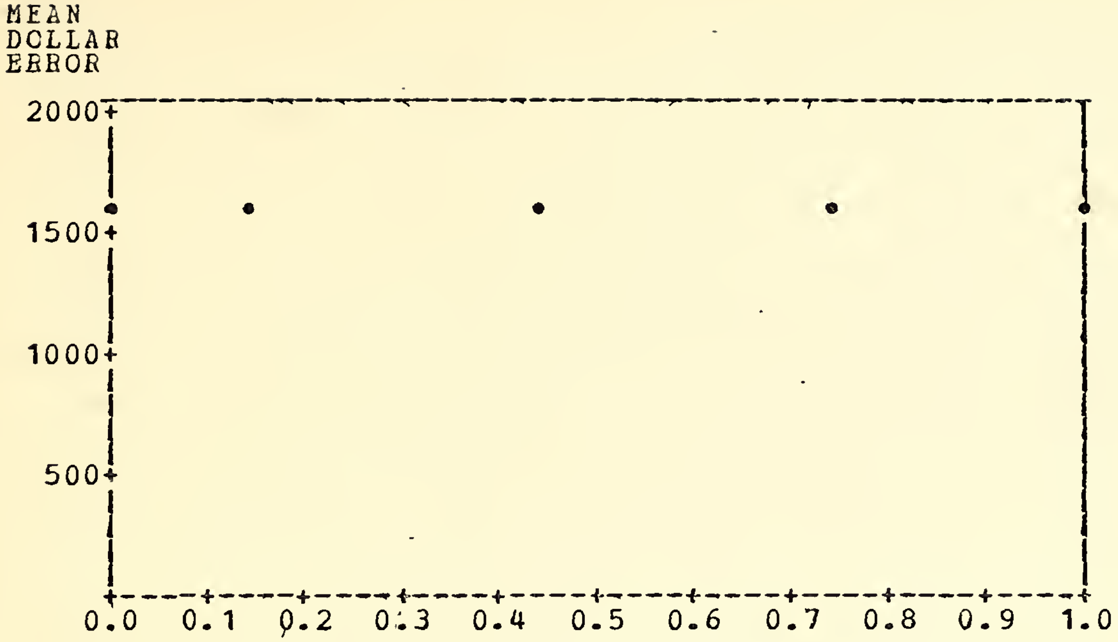
Using the above input data, the total net dollar error increased to $84,000 and the standard deviation of the net error increased to $13,000. The total net dollar error increased from less than one percent to over 11 percent of the payroll dollar value.

C. SENSITIVITY OF MODEL

In view of the change noted when all values are placed at the pessimistic case level, it was decided to investigate the effect of changing one parameter at a time. As would be expected, the error occurrence rate changes and control effectiveness level changes did not all have the same effect on the total system error. Figures 4 thru 9 show the effect of increasing and decreasing the occurrence rates of selected error processes from the base case levels. The interesting fact here is that some of the error occurrence rates have almost no effect on the mean total system error. Any difference in error generated between the two values is masked by the random oscillations of the mean system error about its limiting value. P1 (probability of a document error) is one such variable. One would think that this

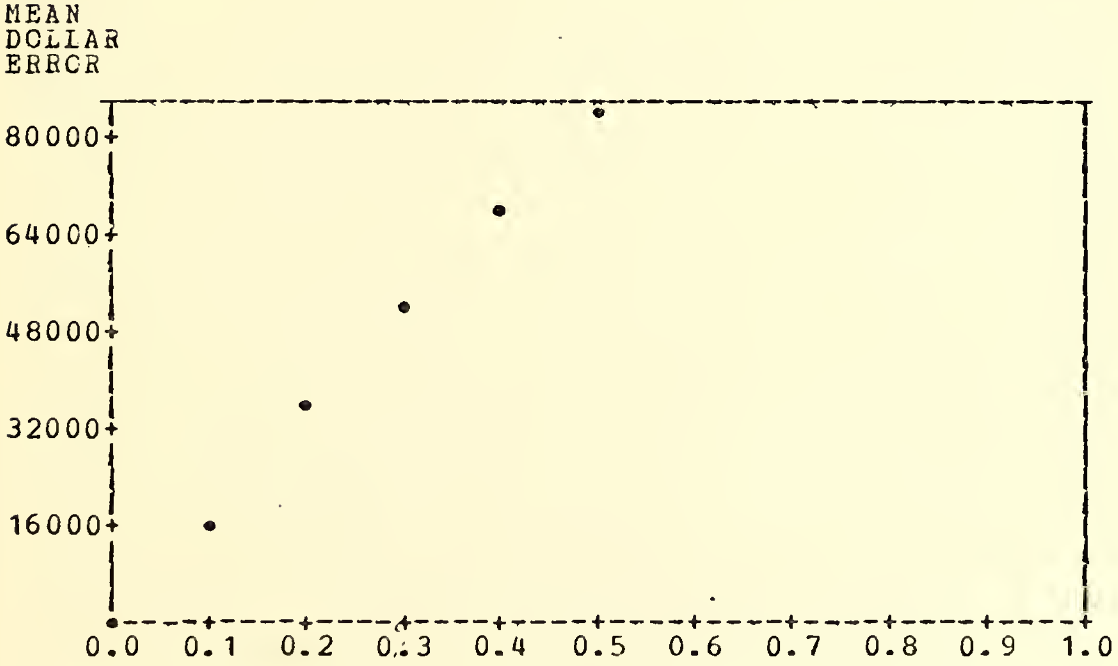
error rate would tend to drive the total system error. It does not. The model was very sensitive to changes in P6 (defalcation errors). In this instance, a change from no defalcation to a rate of 20 in 100 records processed leads to a $137,000 difference in error, which is to be expected in view of the bias introduced into the model by a 20 percent defalcation rate.

Information about the sensitivity of the model to changes in the various parameters provides valuable information to the auditor when developing his audit strategy. For example, the probability of document error, P1, (see figure 4) has almost no effect on the total error generated by the model. This information may lead the auditor to modify his audit strategy from that which he would have used if simulation techniques were not used. As noted in section I.A (page 10), the above process will support step 2 of the major purpose of a preliminary evaluation. In addition, it will aid the auditor in establishing the precision limits for subsequent compliance tests.



PROBABILITY OF DOCUMENT ERROR P1*

FIGURE 4



PROBABILITY OF RECORD TAMPERING ERROR P2*

FIGURE 5

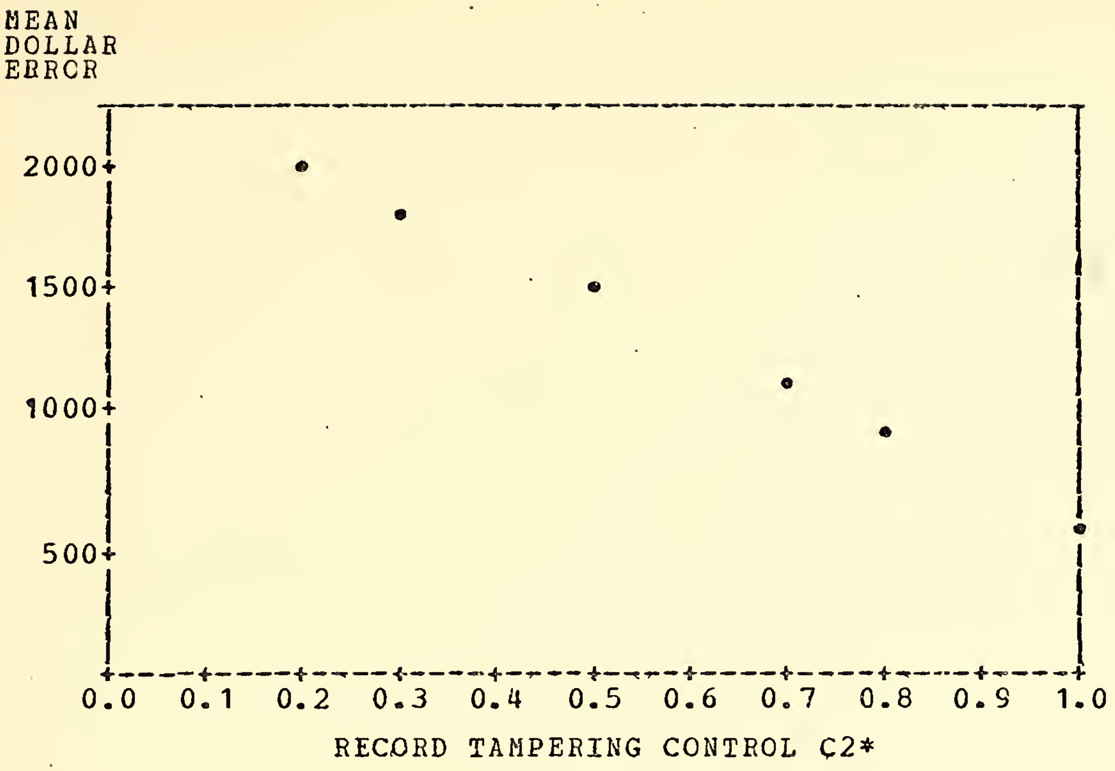


FIGURE 6

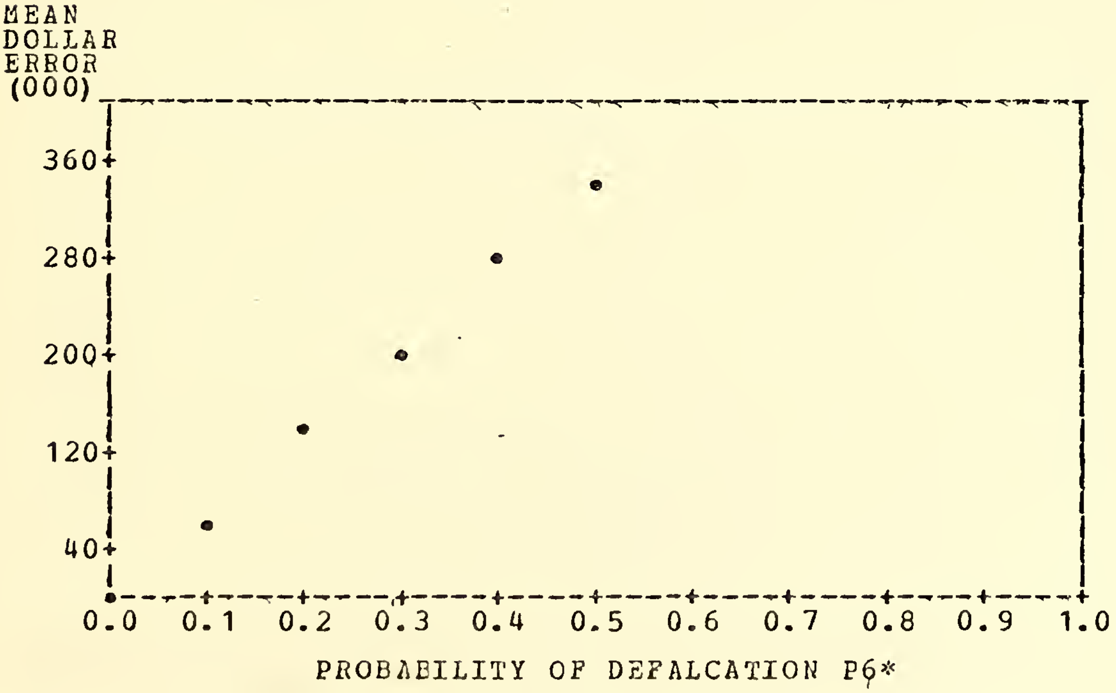
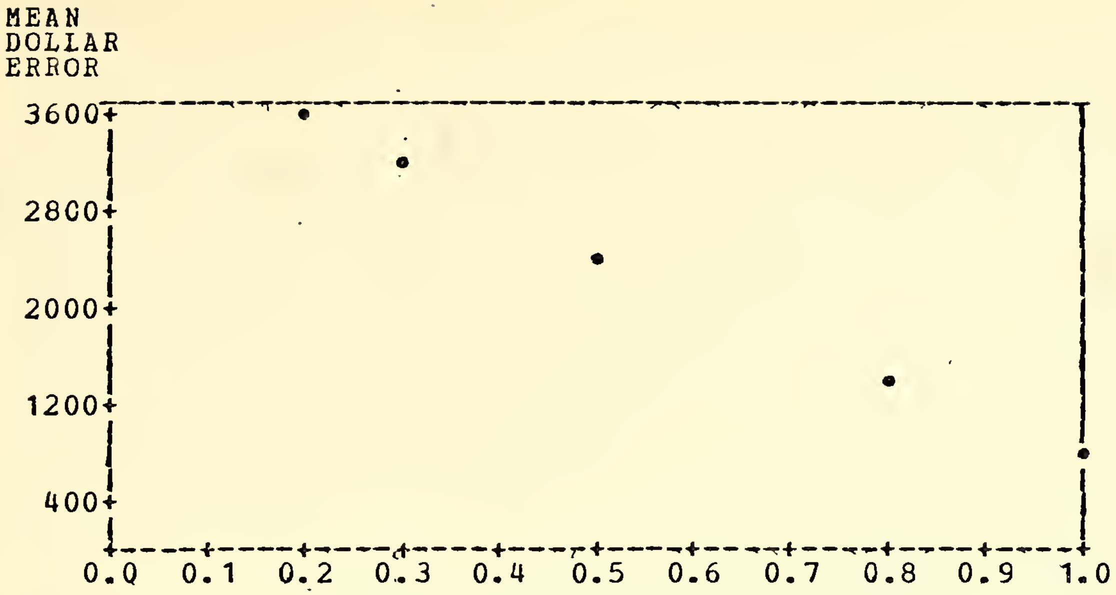
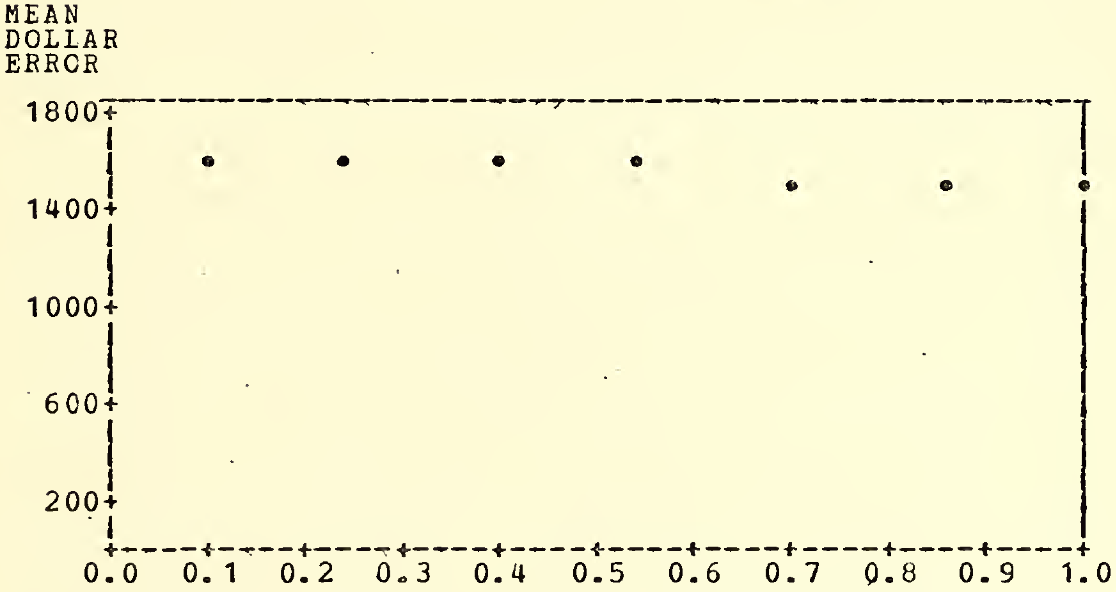


FIGURE 7



DEFALCATION CONTROL C6*

FIGURE 8



CHECK RETURN PROBABILITY C7*

FIGURE 9

*Error occurrence rates and control effectiveness levels are expressed as probabilities.

D. GANGED INTERNAL CONTROL COMPLIANCE RATES

In order to study the over all model response to changes in internal control effectiveness, all internal control rates were varied from 0.0 (absolute ineffectiveness of internal control) to 1.0 (absolute internal control effectiveness). Figures 10 and 11 display the relationship between control effectiveness and the respective mean and standard deviation of the total net system error. The mean appears to be almost linear with the control effectiveness rate but the standard deviation is not linear.

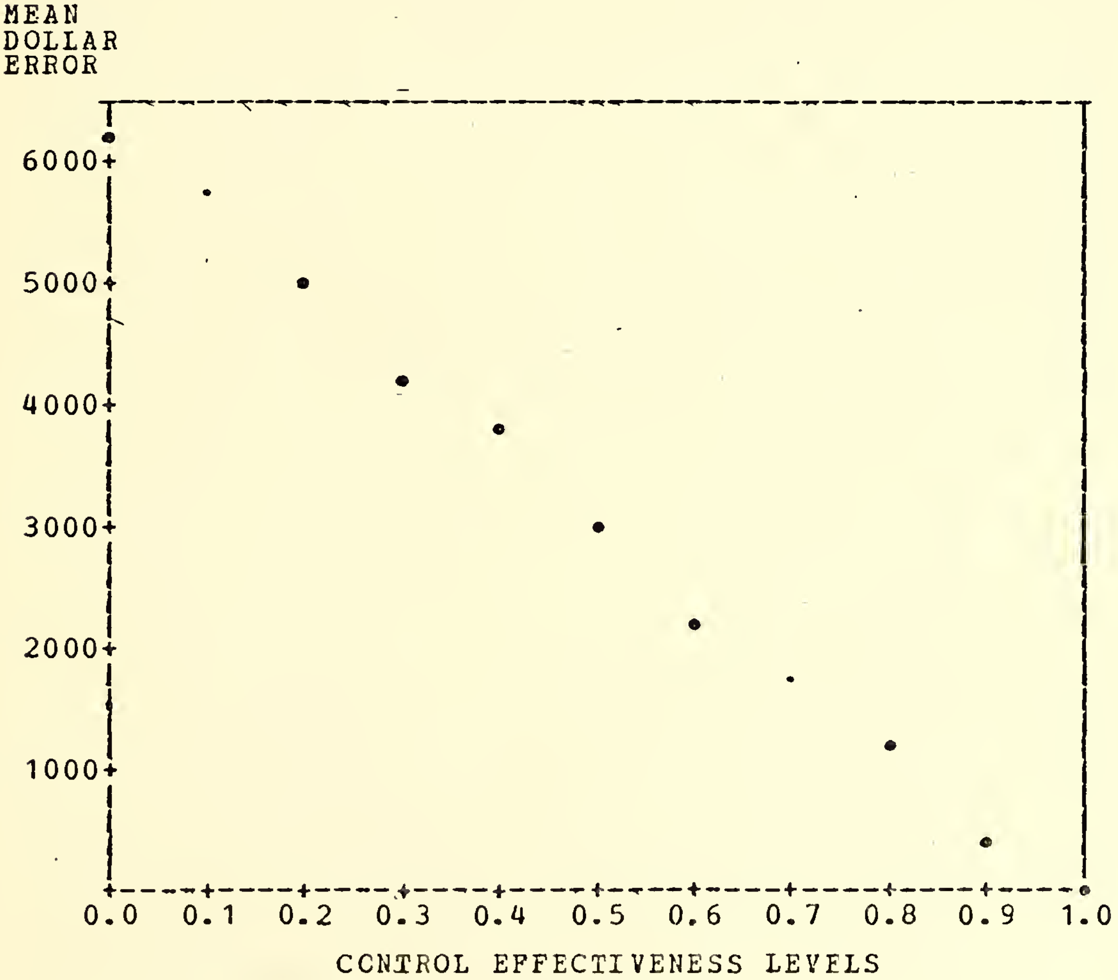


FIGURE 10

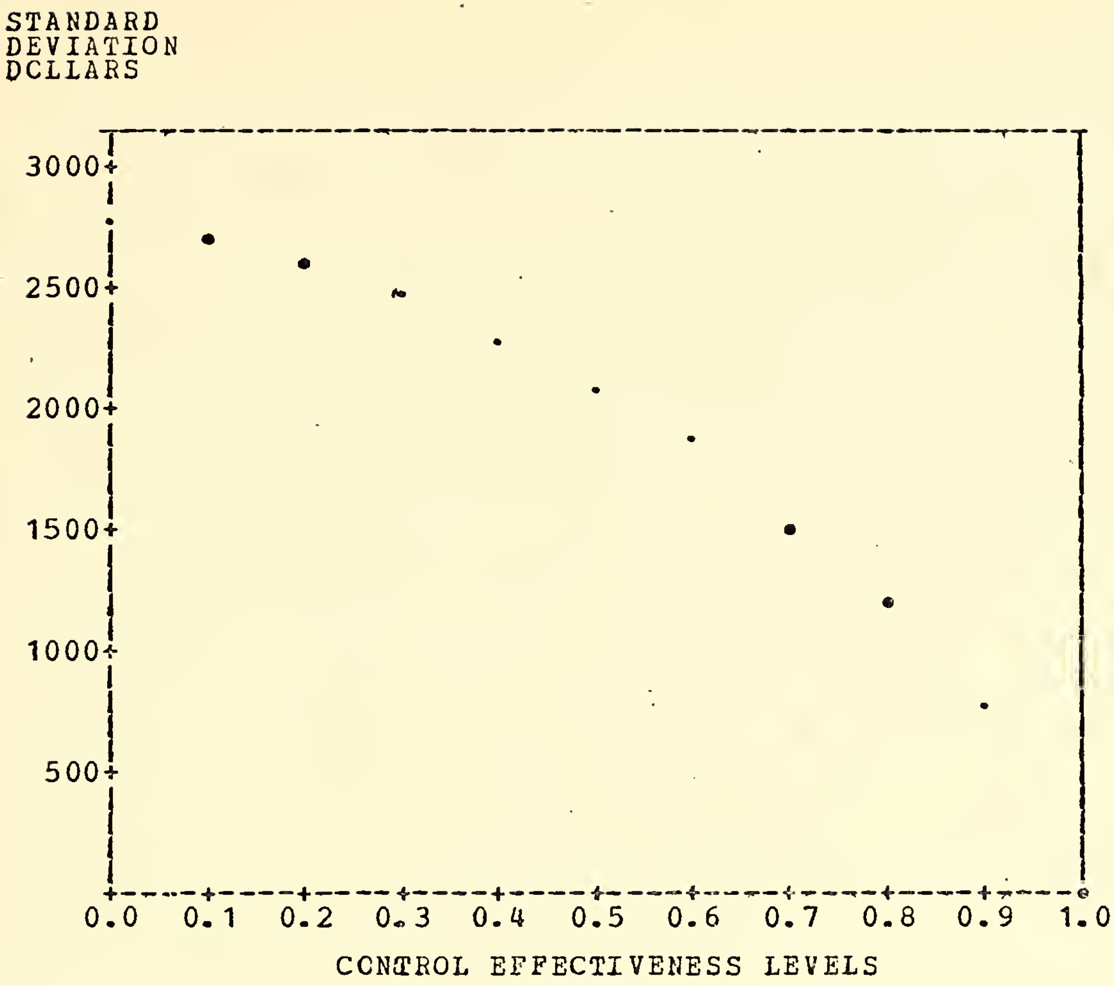

STANDARD
DEVIATION
DOLLARS
3000
2500
2000
1500
1000
500
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
CONTROL EFFECTIVENESS LEVELS

FIGURE 11

V. SUMMARY AND COMMENTS

This thesis has demonstrated the utility of the Monte Carlo simulation technique to the preliminary evaluation of internal controls in an audit engagement. Simulation forces the auditor to systematize his thought process and quantify his impressions concerning potential errors and pertinent controls. It also permits the auditor to gain a more thorough knowledge about the system and the interrelationships of its elements than he can obtain using conceptual methods. This approach provides a rational method to establishing upper precision limits for compliance testing. Sensitivity testing of such models can assist the auditor in identifying material error processes and pertinent control processes. In addition to identifying the strengths and weaknesses for auditing purposes, the simulation model will highlight areas where helpful suggestions can be made to management.

APPENDIX A

DESCRIPTION OF THE SYSTEM

A. THE USNPGS MILITARY PAY SYSTEM

The heart of the pay system at the Postgraduate School is the military disbursing office. The office is staffed with a military Payroll Supervisor and three disbursing clerks. The basic document controlling military pay is the pay record.

Upon induction, enlistment, or commissioning in the Navy, each individual has a pay record created giving the pertinent information required to compute his periodic pay. When transferred, the individual picks up his pay record and proceeds to his duty station. Upon arriving at his new duty station, the individual reports to the military personnel office where his orders are endorsed. The endorsement provides the reporting time and signature of an authorized representative of the commanding officer. The individual then delivers his pay record, detaching endorsement from the previous command, and original orders with reporting endorsement, to the military disbursing office.

The disbursing office takes the pay record and creates a metal plate from a Graphotype machine with name, social security number, pay entry base date, active duty base date, and other identifying data.

During the period the individual is attached to the command, certain adjustments can be made to the pay record to reflect a changed status. These changes reflect a changed marital, dependency, rank or rate status or other pay record modifications. These changes are effected through the receipt in the disbursing office of the appropriate authorizing document from the personnel office.

A certain category of changes can be made based on the

data present in the pay record. The adjustment to base pay based on longevity and FICA withholding will generate changes to the pay record. No other supporting data is required.

An additional category of changes can be requested directly by the individual. In these cases, the individual requests an addition/deletion or changes in an allotment on a standard form which is then processed by the disbursing officer.

The office performs the payroll function for the following categories of personnel:

1. Naval and Coast Guard students assigned to the school for studies.
2. Military faculty members, staff personnel, and curricular officers.
3. Military personnel of the Navy Management Center.
4. Navy personnel attached to the Defense Language Institute.
5. Naval personnel assigned to the Naval Aviation Safety Center.
6. Military personnel of the Naval Reserve Center.
7. Military personnel of the Environmental Prediction Research Facility.
8. Military personnel of the Fleet Numerical Weather Center.
9. Military personnel of the Navy Exchange.
10. Military personnel of the Naval Communications Facility.

B. STEPS IN CREATING THE PAYROLL

Paydays are on the 15th and 30th (last day for February) of the month. The typical pay period covers 15 days. A brief chronological sequence is as follows:

1. Approximately one week prior to the next payday, a money list is created using the Graphotype plates referred

to earlier. The list provides name and social security number for each individual to be paid.

2. The payroll supervisor draws serialized blank checks from the disbursing officer.

3. Using the Graphotype plates, the blank checks are imprinted with names, social security numbers, and student mail center (SMC) numbers (for personnel having SMC boxes).

4. The checks are given to the disbursing clerk maintaining the pay records.

5. The pay record, checks, and money list are inserted into an NCR class 33 accounting machine and the amount of pay due the individuals is printed on the checks, pay records, and money list simultaneously.

6. The machine operator from step 5 and an individual who was not party to the work performed in step 5 compares the amount on the check with the amount entered in the pay record.

7. An adding machine tape is created from the checks and attached to the money list.

8. A disbursing officer's signature plate and the key to a Cummins Check Signer is obtained and the checks are machine dated and signed. The check signing machine count is compared with the number of checks to be issued.

9. Paychecks are distributed.

a. Checks that are to be mailed out are separated and mailed.

b. Student checks are sorted by SMC number and delivered to the student mail center at approximately 7:15 AM on payday. Mail clerks place the checks into the corresponding boxes and the checks are ready for pickup by the individual at 8:00 AM.

c. Military faculty and staff checks are picked up by office representatives who must sign for the checks or an individual can pick up his own check.

d. Representatives from the other activities served by the military disbursing office arrange to pick up their

checks from the military disbursing office. A signed receipt is required for checks distributed in this manner.

10. The money list and all voided checks are sent to the NPGS Controller (fiscal section). They are subsequently forwarded to the Naval Regional Finance Center, Treasure Island.

11. A copy of the money list is filed in the disbursing office.

APPENDIX B

IDENTIFICATION OF ERRORS AND IRREGULARITIES

Neter and Yu defined two types of errors in their study: (1) monetary errors and (2) non-monetary errors. They defined a monetary error to "include any error that can be represented by a $ sign. For example, errors in pay rate, tax deductions, net pay and gross pay fall in this category."[6] They defined non-monetary errors to "include all other errors such as errors in name, social security number, work hours, etc."[7] These same definitions have been adopted for the purpose of this thesis. In evaluating internal controls, the independent auditor is primarily interested in determining the potential impact of any possible undetected monetary errors on the financial accounts. A non-monetary error, although a possible precursor for monetary error, does not directly effect the financial accounts. Non-monetary errors will not be considered explicitly in this Appendix. Only those errors which have direct financial impact will be discussed.

In the process of system operation, several types of monetary errors can be introduced. For the purposes of this paper, the monetary errors will be classified in two major categories. The first category of monetary error is the unintentional error. This category includes all those errors which are introduced into the payroll system through inattention or negligence on the part of the persons operating the system. The second category of monetary error is the intentional error. This category includes those

---

[6] Yu, S. and Neter, J., A Stochastic Model of the Internal Control System, Faculty Working Papers, College of Commerce and Business Administration, University of Illinois, Urbana-Champaign, 17 April, 1973, p6.

[7] Ibid, p6.

errors which are introduced into the system with the full knowledge of the system operator(s). The reasons the operator may do so are manifold. They may range from defalcation to an attempt to cover up a previous unintentional error.

A. UNINTENTIONAL ERRORS

During the payroll system evaluation, it was the writers' impression that unintentional monetary errors could be introduced in the following ways:

1. External Administrative Input Errors

a. Input Document Error

This type of error results from receipt in the payroll department of documents which contain incorrect input data. Such documents may contain non-monetary errors which may escape internal control detection. Examples of such errors which would have a monetary effect are:

(1) Improper Rank/Rate
(2) Incorrect pay entry base date
(3) Incorrect BAQ status
(4) Incorrect number of leave days

b. Input Document Lost

This type of error results from a lack of receipt by the payroll department of documents which if received would have an impact on the financial statements. Examples of such errors are:

(1) Promotion is not reflected
(2) Change in BAQ entitlement not reflected
(3) Change in BAS not reflected
(4) Leave days taken/earned not charged

c. Input Document Not Created

This type of error occurs when the input document is not created at the appropriate time. Errors of this type have an effect identical with the input document

lost type error. The input document not created error will be treated as a subset of the input document lost type error.

2. Internal Administrative Input Error

a. Completion Of FICA Requirements

This type of error results when the completion of payment of the FICA tax obligation is not noted and the required changes made to the pay record.

b. Unrecognized Longevity

This type of error results when a step increase in base pay due to longevity is not recognized and the proper adjusting entry made to the pay record.

3. Clerical Errors

Clerical errors can occur any time a person makes an entry on the pay record. Various types of clerical errors are as follows :

a. Computational

This type of error results when a simple arithmetic error is made in calculation of an individual's pay. This can be the 2+2=5 type or the 6 x 2 = 21 type. In any case, it introduces a monetary error in the financial statements.

b. Transpositional

This type of error results when a correct figure is improperly transferred from one document to another document. For example, $9.85 may be transferred as $9.58.

c. Record Close Out

This type of error results in the creation of a new pay record with improper initial information included in the record. Since a pay record is closed out every six months, this type of error can occur only twice a year.

4. Non-monetary Errors

In general, a non-monetary error will not introduce

an error into the financial statements. However, the failure to include an individual pay record or delete a pay record from the system would result in such misstatements. This is a case where a non-monetary error would effect the financial statements.

B. INTENTIONAL ERRORS

Since intentional errors are the result of overt action by clerks operating the system, the number of ways errors can be introduced is almost infinite. In practice, it could become difficult to determine if, in fact, an error is intentional. Intentional errors could be disguised as an unintentional error by the person who is defalcating. Some of the credible ways intentional errors can be introduced are as follows:

1. Pay Record Modification Errors

This type of error occurs when clerks operating the system modify a pay record to increase the dollar value paid. This could be done by the clerk modifying his own pay record or introducing a bogus record into the system. During the period of transfer, the pay record is in each individual's possession. The individual could, at that time, modify the pay record in such a manner as to increase his take home pay.

2. Theft of Blank Checks

During the interval between receipt at the command of the blank checks and imprinting the payee's name on the check, there exists the possibility of theft and subsequent forgery and cashing of the check.

3. Creation of Unauthorized Check

During the period when the checks are being created, a clerk could introduce an unauthorized check. The check

would then progress through the system and be collected and cashed by the clerk upon signing of the check.

C. EVALUATICN OF IRREGULARITIES

1. Error Magnitude And Frequency

Through discussions with the supervisor and clerks in the payroll department and by observation of them performing their duties, an impression of the frequency and magnitude of the various errors was obtained. The frequency of the error occurrence used in this simulation has no statistical basis in fact, rather, it is a subjective evaluaticn of the system. The magnitude of the errors was arrived at in the same manner. A summary of this evaluation appears on page 28.

2. Internal Control Failure Rate

Using the same technique as above combined with a study of the written internal control procedures, an impression was gained of the internal control failure rate. A quantative impression of this evaluation appears on page 28.

APPENDIX C

DETAILED DESCRIPTION OF SIMULATION MODEL

The defined logic of the program is as follows (see figure 12):

A. The basic data is read into the computer and the various constants are established at their initial values.

B. The program then steps through six statements to determine if any of the six defined errors have been committed. These errors are:

1. An error on an input document (P1).
2. Unauthorized tampering with a pay record (P2).
3. An error developed during the calculation of pay due the employee (P3).
4. The inclusion or exclusion of a pay record from the payroll (P4).
5. An error committed while entering the amount of pay on the check, pay record, and money list during the NCR machine operation (P5).
6. An error due to defalcation (P6).

Each of the above errors are discussed in Appendix B (Identification of Errors and Irregularities). The decision which determines the presence or lack of presence of an error is developed by comparing a random real number between zero and one with the given occurrence rate. If the number exceeds the occurrence rate, then the event the occurrence rate described did not occur.

C. If an error is detected as described above, the program will branch to a control statement. This statement will determine if the control has failed. If the control detected the error, the program will return to the main stream. If the control failed, the program will then go to a routine to calculate the error introduced. The controls are identified C1 thru C6 and are associated with P1 thru

P6. Each determination of failure or no failure is developed in a manner identical to that used to determine the presence of an error.

D. If an error is detected and the control fails, an error is generated. The size and nature of the error is determined by the cause of the error. The error magnitudes are generated by the model using the following logic:

1. Error on an input document (P1). The error is assumed to be normally distributed with a mean U1 and a standard deviation of S1. The output value of this error is developed by calling a number from a normally distributed set of random numbers (The numbers have a mean of zero and a standard deviation of one.) Multiplying this number by S1 and adding it to U1 yields the error. Both S1 and U1 can be defined by the basic input data.

2. Pay record tampering (P2). This error is calculated in a fashion identical to the calculation for input document error except that the variables are defined as U2 and S2.

3. Pay calculation error (P3). This error is calculated slightly different than the above errors. In this case, a random number between zero and one is obtained. This number is then compared against a cumulative probability distribution and a basic pay is selected. The cumulative probability distribution of the basic pay was developed from the payroll distribution at the facility that was modeled. The basic pay, once selected, is multiplied by 0.05 and either added to or subtracted from the error depending on the sign of a random number from the normal distribution.

4. Pay record inclusion/exclusion error (P4). This error essentially is the inclusion or exclusion of a pay record from the payroll. PI is the probability that a pay record is included in the payroll when, in fact, it should have been excluded. Again, a random number between zero and one is selected and compared to PI and also a basic pay is

selected. If the pay is to be included as a result of the random number versus PI comparison, the basic pay selected is added to the error. If, on the other hand, the pay is excluded, the basic pay is subtracted from the error.

5. NCR machine error (P5). This error is generated in a manner identical to P1 and P2.

6. Defalcation (P6). This error is generated in a manner identical to P1 and P2 except that if the error is found to be negative the value is not added to the payroll error.

E. Each of the above errors are calculated as they occur. Errors generated by P1, P3, P4, and P5 are summed and passed to control C7 (described below). Errors generated by P2 and P6 bypass C7 and are added directly to the total payroll error being accumulated for each payday.

F. Errors P1, P3, P4, and P5 will result in an error in the pay check received by an employee. A determination of honesty is made by comparing a random number to the check return probability C7. The errors are not added into the total if the check is returned. If, however, the test indicates the check is not returned, the sign of the error is tested. If the error is negative, the value is not added into the total error. If the value is positive, the magnitude of the error is compared with a random value selected from a normally distributed variate whose mean is U7 and standard deviation is S7. If the magnitude of the error is less than this number, the error is added directly to the total payroll error.

G. The above description describes the flow of logic for one check. If the total payroll consists of K checks, the cycle is repeated until the number of checks is equal to K. During the processing of checks, a cumulative total is kept of the error. When the proper number of checks has been processed, the resulting error is the value used for that payroll. A number of separate payroll errors are generated and a mean error is determined and a standard

deviation is calculated.

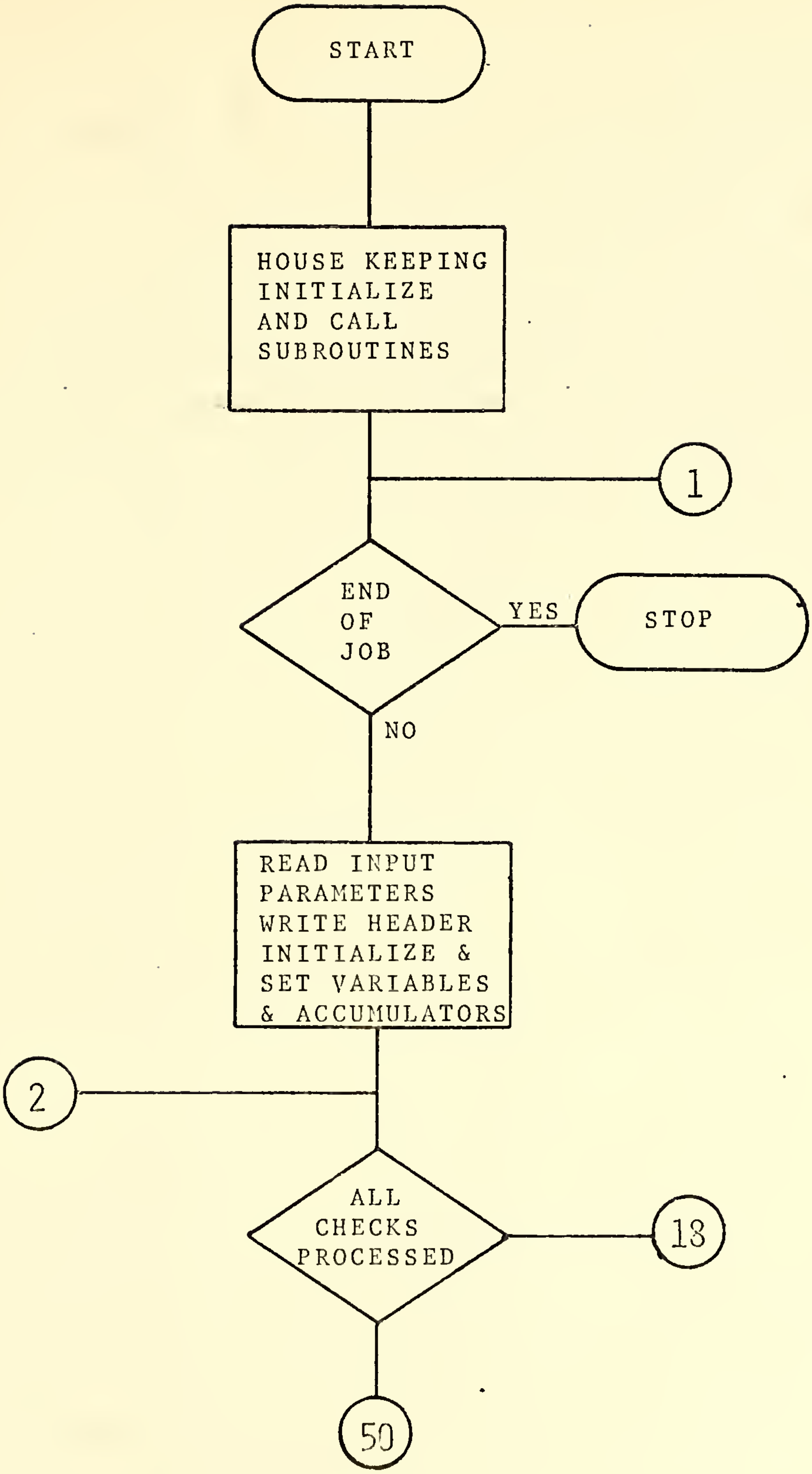

START
HOUSE KEEPING INITIALIZE AND CALL SUBROUTINES
1
END OF JOB
YES
STOP
NO
READ INPUT PARAMETERS WRITE HEADER INITIALIZE & SET VARIABLES & ACCUMULATORS
2
ALL CHECKS PROCESSED
13
50

FIGURE 12A

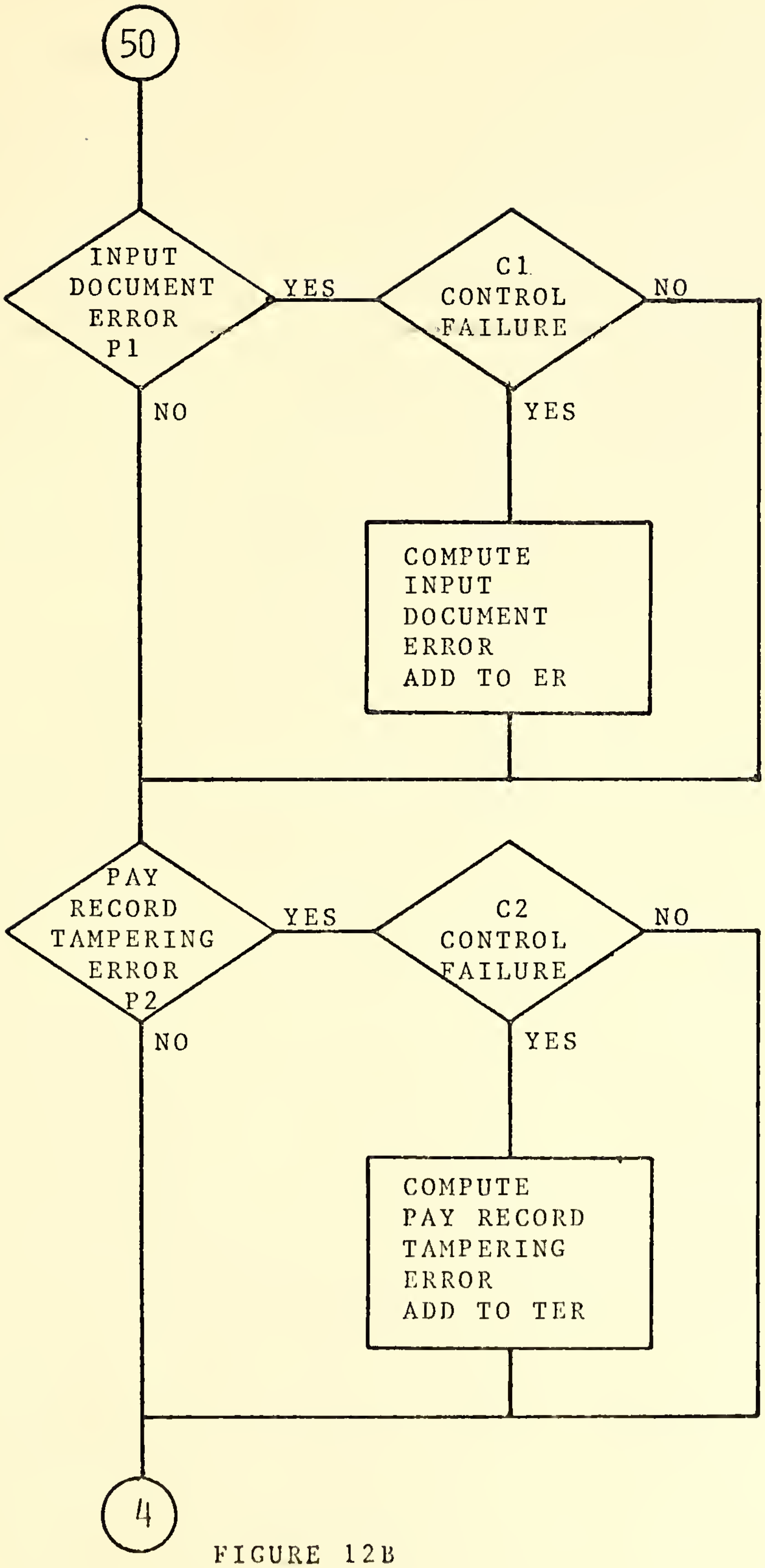

50
INPUT DOCUMENT ERROR P1
YES
C1 CONTROL FAILURE
NO
NO
YES
COMPUTE INPUT DOCUMENT ERROR ADD TO ER
PAY RECORD TAMPERING ERROR P2
YES
C2 CONTROL FAILURE
NO
NO
YES
COMPUTE PAY RECORD TAMPERING ERROR ADD TO TER
4

FIGURE 12B

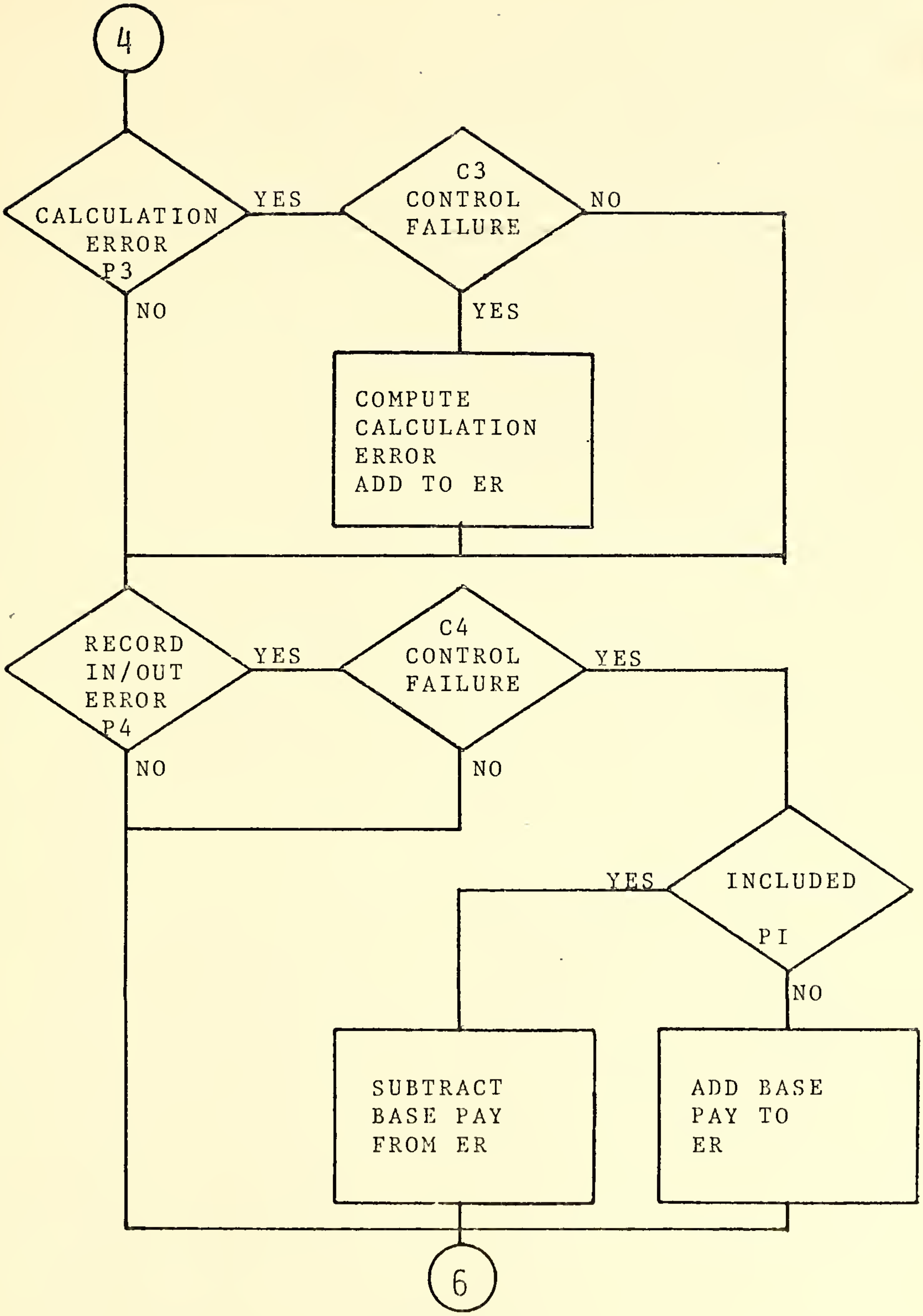

4
CALCULATION ERROR P3
YES
C3 CONTROL FAILURE
NO
NO
YES
COMPUTE CALCULATION ERROR ADD TO ER
RECORD IN/OUT ERROR P4
YES
C4 CONTROL FAILURE
YES
NO
NO
YES
INCLUDED PI
NO
SUBTRACT BASE PAY FROM ER
ADD BASE PAY TO ER
6

FIGURE 12C

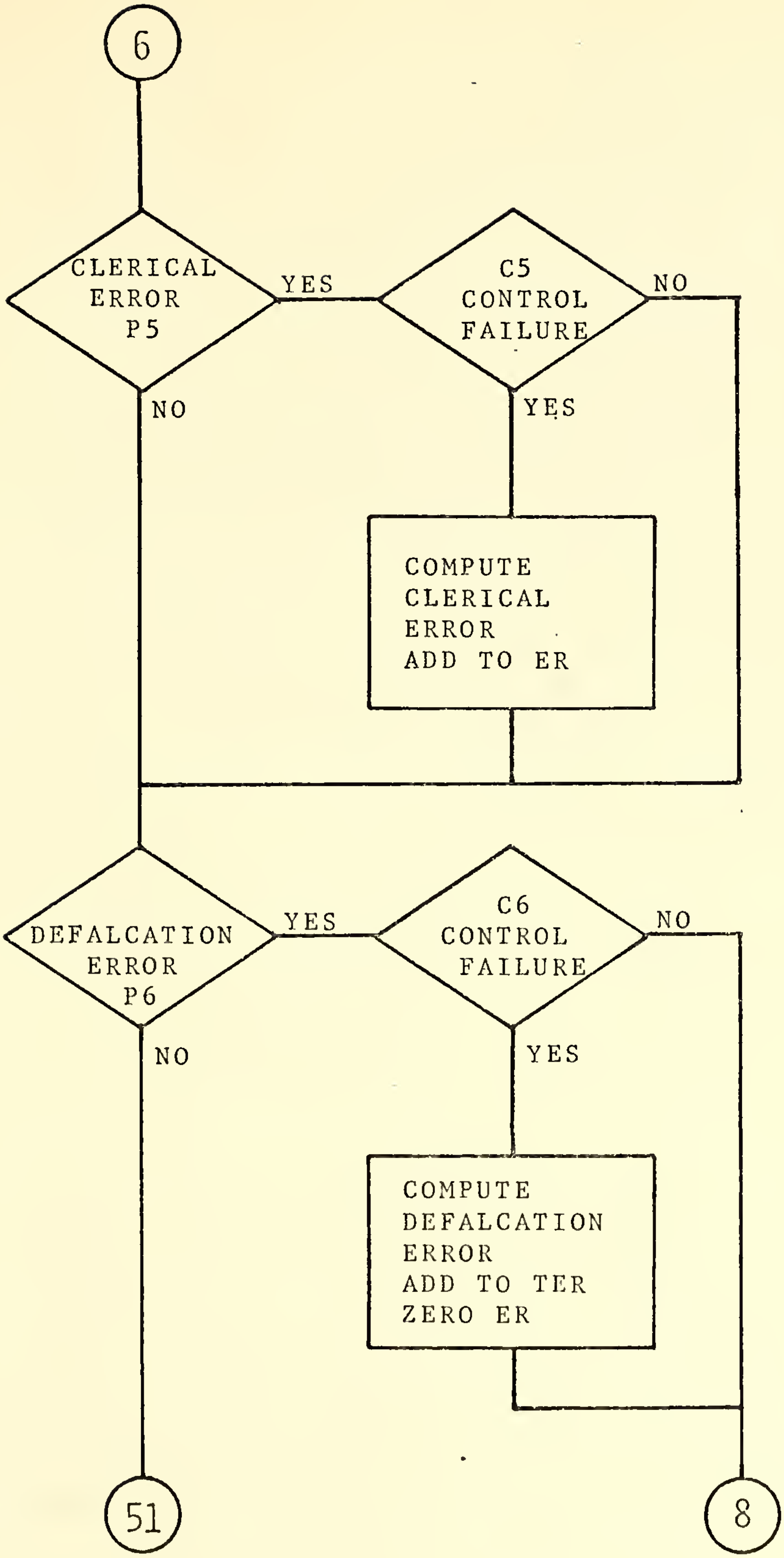

6
CLERICAL ERROR P5
YES
C5 CONTROL FAILURE
NO
NO
YES
COMPUTE CLERICAL ERROR ADD TO ER
DEFALCATION ERROR P6
YES
C6 CONTROL FAILURE
NO
NO
YES
COMPUTE DEFALCATION ERROR ADD TO TER ZERO ER
51
8

FIGURE 12D

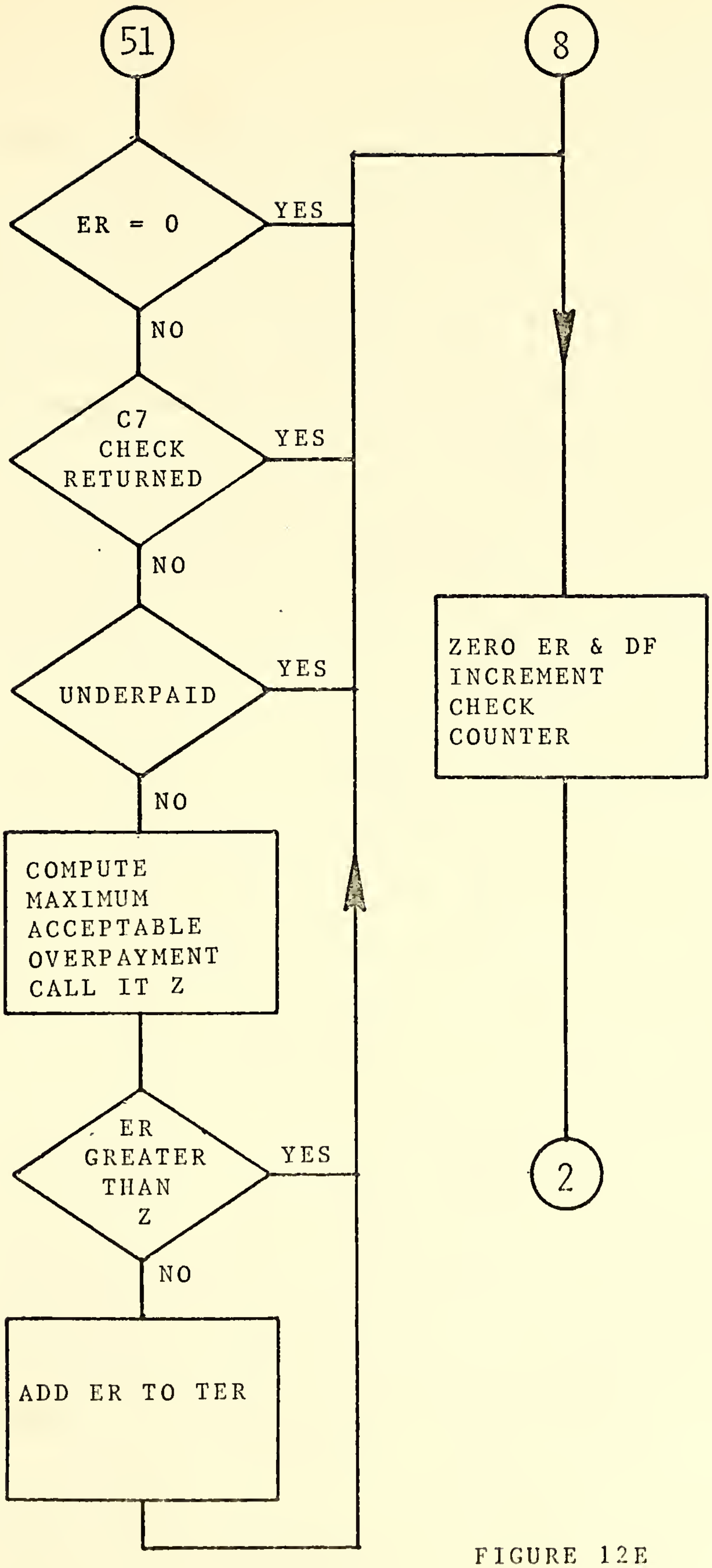

51
ER = 0
YES
NO
C7 CHECK RETURNED
YES
NO
UNDERPAID
YES
NO
COMPUTE MAXIMUM ACCEPTABLE OVERPAYMENT CALL IT Z
ER GREATER THAN Z
YES
NO
ADD ER TO TER
8
ZERO ER & DF
INCREMENT CHECK COUNTER
2

FIGURE 12E

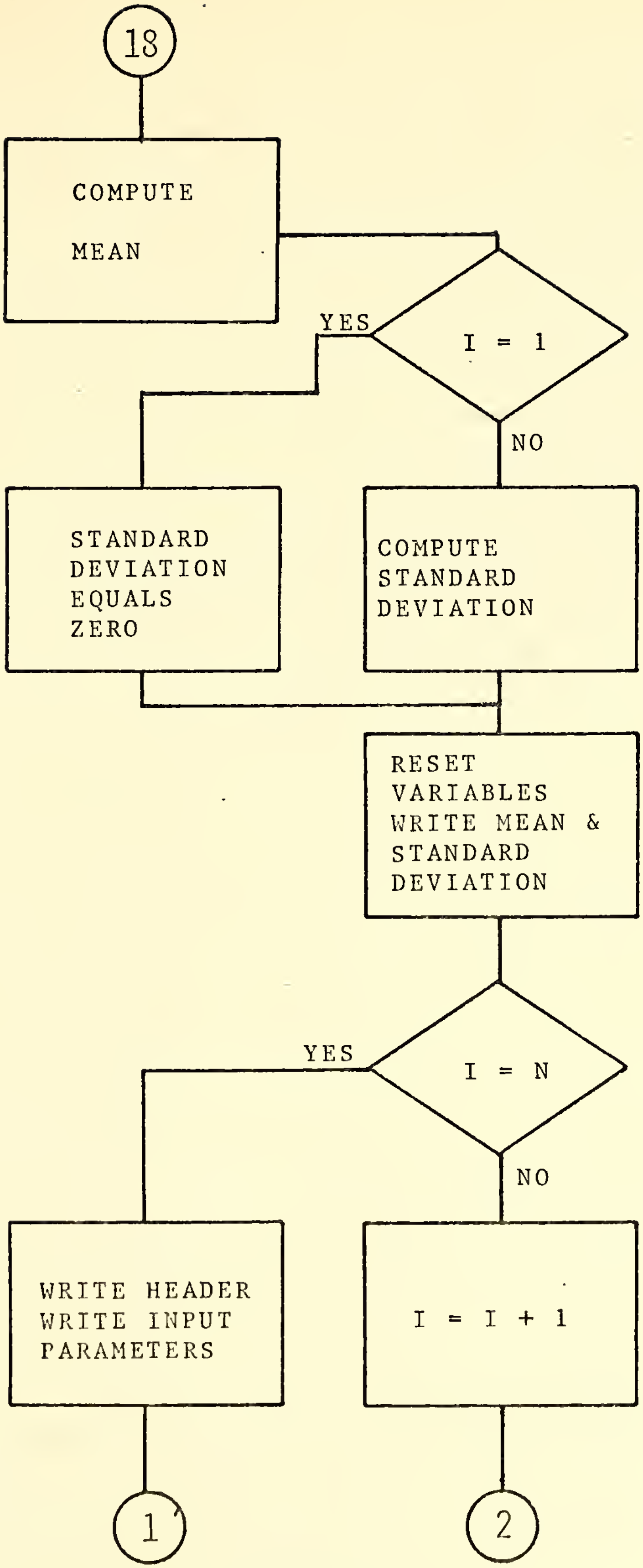

18
COMPUTE MEAN
I = 1
YES
NO
STANDARD DEVIATION EQUALS ZERO
COMPUTE STANDARD DEVIATION
RESET VARIABLES WRITE MEAN & STANDARD DEVIATION
I = N
YES
NO
WRITE HEADER WRITE INPUT PARAMETERS
I = I + 1
1
2

FIGURE 12F

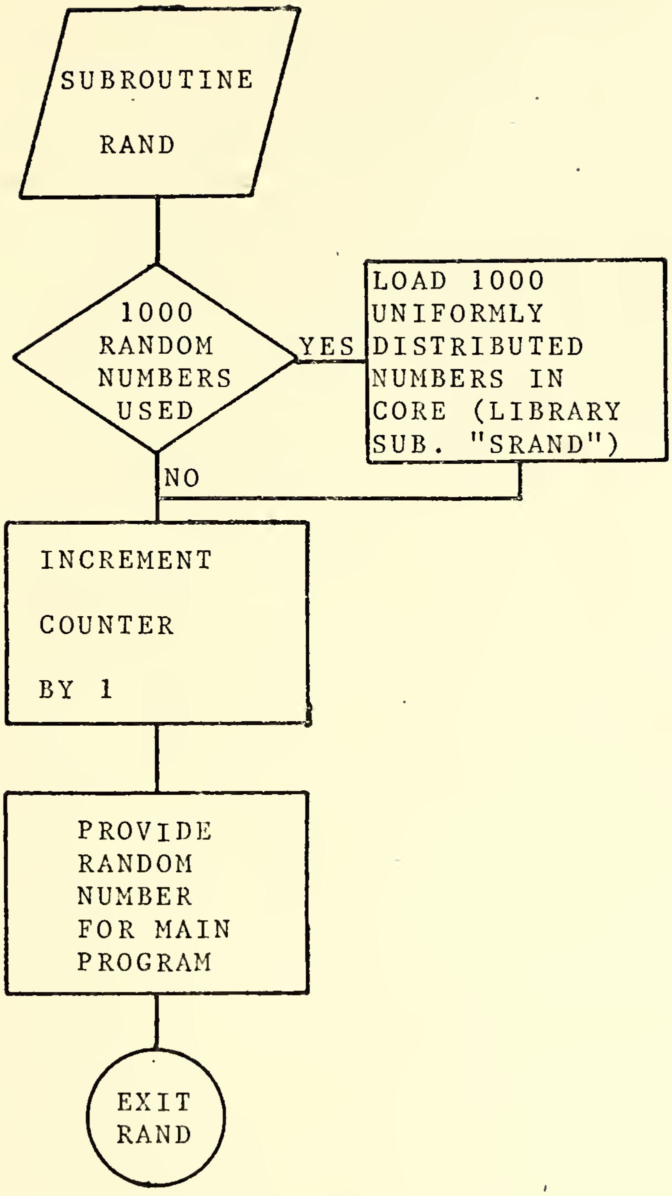

SUBROUTINE
RAND
1000
RANDOM
NUMBERS
USED
YES
LOAD 1000
UNIFORMLY
DISTRIBUTED
NUMBERS IN
CORE (LIBRARY
SUB. "SRAND")
NO
INCREMENT
COUNTER
BY 1
PROVIDE
RANDOM
NUMBER
FOR MAIN
PROGRAM
EXIT
RAND

FIGURE 12G

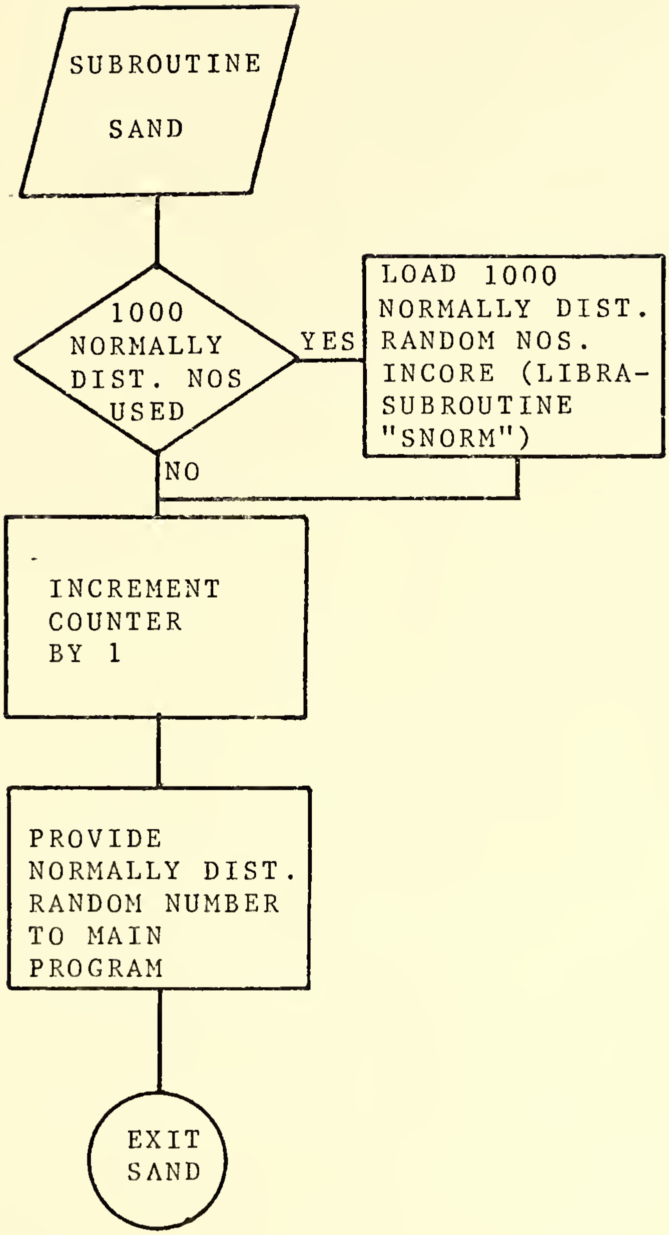

SUBROUTINE
SAND
1000
NORMALLY
DIST. NOS
USED
YES
LOAD 1000
NORMALLY DIST.
RANDOM NOS.
INCORE (LIBRA-
SUBROUTINE
"SNORM")
NO
INCREMENT
COUNTER
BY 1
PROVIDE
NORMALLY DIST.
RANDOM NUMBER
TO MAIN
PROGRAM
EXIT
SAND

FIGURE 12H

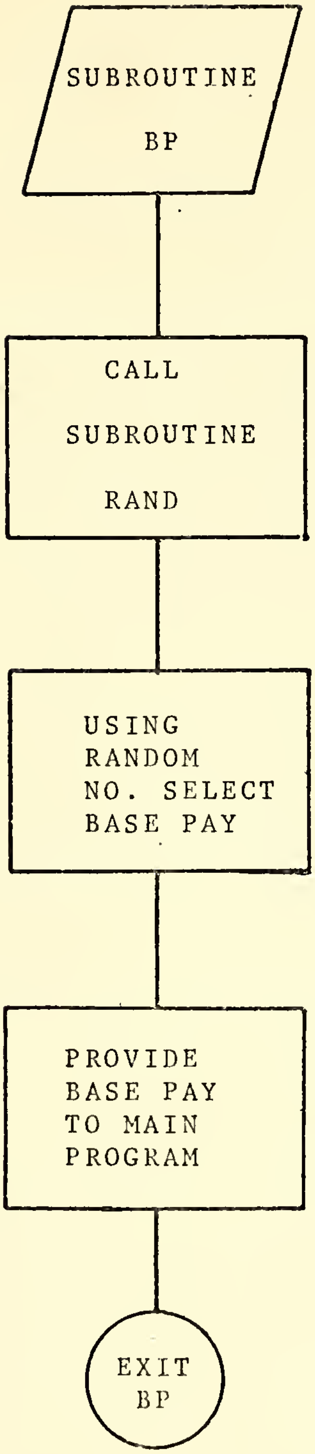

SUBROUTINE
BP
CALL
SUBROUTINE
RAND
USING
RANDOM
NO. SELECT
BASE PAY
PROVIDE
BASE PAY
TO MAIN
PROGRAM
EXIT
BP

FIGURE 12I

SAMPLE COMPUTER OUTPUT

```
                          PAYROLL SIMULATION MODEL
1700 CHECKS HAVE BEEN PROCESSED
500 SEPARATE RUNS HAVE BEEN MADE

          I          U             S
         001       0760.31       0000.00
         002       1955.19       1689.82
         003       1543.94       1391.08
         004       1237.63       1290.50
          "          "             "
          "          "             "
          "          "             "
          "          "             "
         495       1560.32       1476.83
         496       1558.28       1476.05
         497       1563.08       1478.44
         498       1562.65       1476.98
         499       1561.19       1475.86
         500       1560.86       1473.39
                             P          C          U          S
DOCUMENT ERROR           0.150000   0.800000     50.00      50.00
RECORD TAMP. ERROR       0.005000   0.500000    200.00      50.00
CALC ERROR               0.100000   0.950000
RECORD IN/OUT ERROR      0.010000   0.950000  0.250000
CLERICAL ERROR           0.100000   0.950000      0.00     100.00
DEFALCATION ERROR        0.001000   0.800000   2000.00    1000.00
CHECK RETURN ERROR                  0.850000      0.00      40.00

PAY DIST.   0.091  0.139  0.185  0.229  0.252  etc.
PAY RATE.   350.0  425.0  450.0  600.0  775.0  etc.
                              END THIS RUN
```

COMPUTER PROGRAM

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C             PAYROLL COMPUTER SIMULATION MODEL            C
C                            MAIN                          C
C                                                          C
C    TWO LIBRARY SUBROUTINES ARE CALLED AS FOLLOWS:        C
C       1. SRAND PROVIDES SHUFFLED RANDOM NUMBERS BETWEEN  C
C          ZERO AND ONE.                                   C
C       2. SNORM PROVIDES SHUFFLED RANDOM NORMAL NUMBERS   C
C          WITH  A MEAN OF ZERO AND A STANDARD DEVIATION   C
C          OF ONE.                                         C
C   THREE SUB-ROUTINES ARE CALLED BY THE MAIN PROGRAM      C
C   AS FOLLOWS:                                            C
C       1. RAND STORES 1000 RANDOM NUMBERS FROM SRAND FOR  C
C          USE BY THE MAIN PROGRAM.                        C
C       2. SAND STORES 1000 NORMALLY DISTRIBUTED RANDOM    C
C          NUMBERS FOR USE BY THE MAIN PROGRAM.            C
C     3. BP PROVIDES BASE PAY DATA TO THE MAIN PROGRAM.    C
C   INPUT DATA IS DEFINED AS FOLLOWS:                      C
C       P1  PROBABILITY OF INPUT DOCUMENT ERROR            C
C       P2  PROBABILITY OF RECORD TAMPERING                C
C       P4  PROBABILITY OF RECORD IN/OUT ERROR             C
C       P3  PROBABILITY OF CALCULATION ERROR               C
C       P5  PROBABILITY OF CLERICAL ERROR                  C
C       P6  PROBABILITY OF DEFALCATION                     C
C       C1  INTERNAL CONTROL RATE FOR P1 ERROR             C
C       C2  INTERNAL CONTROL RATE FOR P2 ERROR             C
C       C3  INTERNAL CONTROL RATE FOR P3 ERROR             C
C       C4  INTERNAL CONTROL RATE FOR P4 ERROR             C
C       C5  INTERNAL CONTROL RATE FOR P5 ERROR             C
C       C6  INTERNAL CONTROL RATE FOR P6 ERROR             C
C       C7  PROBABILITY OF RETURN OF INCORRECT CHECK       C
C       U1  MEAN OF INPUT DOCUMENT ERROR                   C
C       U2  MEAN OF RECORD TAMPERING ERROR                 C
C       U5  MEAN OF CLERICAL ERROR                         C
C       U6  MEAN OF DEFALCATION                            C
```

```
C       U7  MEAN OF CHECK RETURN CONTROL                   C
C       S1  STANDARD DEVIATION OF U1                       C
C       S2  STANDARD DEVIATION OF U2                       C
C       S5  STANDARD DEVIATION OF U5                       C
C       S6  STANDARD DEVIATION OF U6                       C
C       S7  STANDARD DEVIATION OF U7                       C
C       PI  PROBABILITY OF INCLUSION OF IMPROPER RECORD    C
C        I  SEED NUMBER TO START THE RANDOM NUMBER CHAIN   C
C        A  STORAGE AREA FOR RANDOM NUMBERS                C
C        B  STORAGE AREA FOR NORMAL RANDOM NUMBERS         C
C       IO  INDEX FOR A STORAGE AREA                       C
C       I1  INDEX FOR B STORAGE AREA                       C
C        K  NUMBER OF CHECKS TO BE PROCESSED               C
C        N  NUMBER OF ITERATIONS TO BE DONE                C
C        C  CUMULATIVE DISTRIBUTION OF PAY RATES           C
C        D  PAY RATES                                      C
C        J  COUNTER TO INDICATE NUMBER OF CHECKS PROCESSED C
C        I  COUNTER TO INDICATE NUMBER OF ITERATIONS       C
C       ER  TOTAL ERROR ACCUMULATED ON JTH CHECK           C
C      TER  TOTAL ERROR ACCUMULATED ON JTH RUN             C
C     STER  SUM OF TOTAL ERRORS                            C
C    STER2  SUM OF TOTAL ERRORS  SQUARED                   C
C        X  DUMMY VARIABLE USED FOR RANDOM NUMBER          C
C     XBAR  MEAN VALUE OF TER                              C
C    SIGMA  STANDARD DEVIATION OF XBAR                     C
C                                                          C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      DIMENSION A(1000), B(1000), C(12), D(12)
      COMMON A,B,I0,I1,C,D,L
      CALL OVFLOW
      L=549236
      CALL SRAND (L,A,1000)
      CALL SNORM (L,B,1000)
      I0=1
      I1=1
C READ INPUT DATA
```

```
    1 READ (5,23,END=22) P1,C1,U1,S1
      READ (5,23) P2,C2,U2,S2
      READ (5,23) P3,C3
      READ (5,23) P4,C4,PI
      READ (5,23) P5,C5,U5,S5
      READ (5,23) P6,C6,U6,S6
      READ (5,23) C7,U7,S7
      READ (5,34) K
      READ (5,34) N
      READ (5,32) C
      READ (5,32) D
C TITLE OUTPUT AND READ K AND N
      WRITE (6,35)
      WRITE (6,36) K
      WRITE (6,37) N
      WRITE (6,38)
C INITIALIZE VARIABLES
      J=1
      I=1
      ER=0
      TER=0
      STER=0
      STER2=0
    2 CONTINUE
C CHECK TO SEE IF K CHECKS PROCESSED
      IF (J.GT.K) GO TO 18
C CHECK TO SEE IF P1 ERROR COMMITTED
      CALL RAND (X)
      IF (X.LE.P1) GO TO 9
C CHECK TO SEE IF P2 ERROR COMMITTED
    3 CALL RAND (X)
      IF (X.LE.P2) GO TO 10
C CHECK TO SEE IF P3 ERROR COMMITTED
    4 CALL RAND (X)
      IF (X.LE.P3) GO TO 11
C CHECK TO SEE IF P4 ERROR COMMITTED
```

```
    5 CALL RAND (X)
      IF (X.LE.P4) GO TO 14
C CHECK TO SEE IF P5 ERROR COMMITTED
    6 CALL RAND (X)
      IF (X.LE.P5) GO TO 16
C CHECK TO SEE IF P6 ERROR COMMITTED
    7 CALL RAND (X)
      IF (X.LE.P6) GO TO 17
      IF (ER.EQ.0) GO TO 8
C CHECK TO SEE IF PAYCHECK RETURNED
      CALL RAND (X)
      IF (X.LE.C7) GO TO 8
      IF (ER.LT.U7) GO TO 8
      CALL SAND (X)
      Z=X*S7
      IF (ER.GT.Z) GO TO 8
      TER=TER+ER
C INITIALIZE VARIABLES FOR NEXT CHECK
    8 DF=0
      ER=0
      J=J+1
      GO TO 2
C CHECK TO SEE IF CONTROL WORKS AND CALCULATE SIZE
C OF A P1 ERROR
    9 CALL RAND (X)
      IF (X.LE.C1) GO TO 3
      CALL SAND (X)
      ER1=X*S1+U1
      ER=ER+ER1
      GO TO 3
C CHECK TO SEE IF CONTROL WORKS AND CALCULATE SIZE
C OF A P2 ERROR
   10 CALL RAND (X)
      IF (X.LE.C2) GO TO 4
      CALL SAND (X)
      ER2=X*S2+U2
```

```
      TER=TER+ER2
      GO TO 4
C CHECK TO SEE IF CONTROL WORKS AND CALCULATE SIZE
C OF A P3 ERROR
   11 CALL RAND (X)
      IF (X.LE.C3) GO TO 5
      CALL BP (Y)
      Z=Y*.05
      CALL SAND (X)
      IF (X) 12,13,13
   12 ER=ER-Z
      GO TO 5
   13 ER=ER+Z
      GO TO 5
C CHECK TO SEE IF CONTROL WORKS AND CALCULATE SIZE
C OF A P4 ERROR
   14 CALL RAND (X)
      IF (X.LE.C4) GO TO 6
      CALL BP (Y)
      CALL RAND (X)
      IF (PI.GE.X) GO TO 15
      ER=ER-Y
      GO TO 6
   15 ER=ER+Y
      GO TO 6
C CHECK TO SEE IF CONTROL WORKS AND CALCULATE SIZE
C OF A P5 ERROR
   16 CALL RAND (X)
      IF (X.LE.C5) GO TO 7
      CALL SAND (X)
      ER5=X*S5+U5
      ER=ER+ER5
      GO TO 7
C CHECK TO SEE IF CONTROL WORKS AND CALCULATE SIZE
C OF A P6 ERROR
   17 CALL RAND (X)
```

```
      IF (X.LE.C6) GO TO 8
      CALL SAND (X)
      DF=X*S6+U6
      IF (DF.LT.0.0) GO TO 8
      TER=TER+DF
      ER=0
      GO TO 8
C CALCULATES MEAN AND STANDARD DEVIATION
   18 STER=STER+TER
      STER2=STER2+TER**2
      XBAR=STERI
      IF (I.EQ.1) GO TO 19
      XBA2=XBAR*XBAR
      SIGMA=((STER2-(I*XBA2))(I-1))**.5
      GO TO 20
   19 SIGMA=0
   20 J=1
      ER=0
C WRITES OUTPUT
      WRITE (6,25) I,XBAR,SIGMA
      TER=0
      IF (I.GE.N) GO TO 21
      I=I+1
      GO TO 2
C WRITES BASIC INPUT VARIABLES
   21 WRITE (6,39)
      WRITE (6,24)
      WRITE (6,26) P1,C1,U1,S1
      WRITE (6,27) P2,C2,U2,S2
      WRITE (6,28) P3,C3
      WRITE (6,29) P4,C4,PI
      WRITE (6,30) P5,C5,U5,S5
      WRITE (6,31) P6,C6,U6,S6
      WRITE (6,33) C7,U7,S7
      WRITE (6,40) C
      WRITE (6,42) D
```

```
      WRITE (6,41)
      GO TO 1
   22 STOP
   23 FORMAT (4F10.2)
   24 FORMAT (' ',28X,'P',15X,'C',15X,'U',15X,'S')
   25 FORMAT (5X,I4,2(2X,F10.2))
   26 FORMAT (' ','DOCUMENT ERROR',4X,2(5X,F10.6),
     1 2(5X,F10.2))
   27 FORMAT (' ','RECORD TAMP. ERROR',2(5X,F10.6),
     1 2(5X,F10.2))
   28 FORMAT (' ','CALC ERROR',8X,2(5X,F10.6))
   29 FORMAT (' ','RECORD INOUT ERROR',4X,F10.6,2(5X,F10.6))
   30 FORMAT (' ','CLERICAL ERROR',4X,2(5X,F10.6),
     1 2(5X,F10.2))
   31 FORMAT (' ','DEFALCATION ERROR',1X,2(5X,F10.6),
     1 2(5X,F10.2))
   32 FORMAT (12F6.2)
   33 FORMAT (' ','CHECK RETURN ERROR',20X,F10.6,
     12(5X,F10.2))
   34 FORMAT (I4)
   35 FORMAT ('1',20X,'PAYROLL SIMULATION MODEL')
   36 FORMAT ('0',10X,I4,3X,'CHECKS HAVE BEEN PROCESSED')
   37 FORMAT (' ',10X,I4,3X,'SEPARATE RUNS HAVE BEEN MADE')
   38 FORMAT (8X,'I',8X,'U',11X,'S')
   39 FORMAT ('0',55X,'DATA')
   40 FORMAT (' ',10X,'PAY DIST.',4X,12(1X,F6.3))
   41 FORMAT ('0',50X,'END THIS RUN')
   42 FORMAT (' ',10X,'PAY RATE',4X,12(1X,F6.1))
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                      SUBROUTINE RAND                     C
C    THIS SUBROUTINE CALLS AND STORES 1000 RANDOM NUMBERS, C
C    COUNTS THE NUMBERS AS USED AND REFILLS THE STORAGE    C
C    AREA WHEN 1000 NUMBERS HAVE BEEN CALLED               C
C                                                          C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
```

```
      SUBROUTINE RAND (R)
      COMMON A,B,I0,I1,C,D,L
      DIMENSION A(1000), B(1000), C(12), D(12)
      R=A(I0)
      I0=I0+1
      IF (I0.GT.999) GO TO 1
      RETURN
    1 CALL SRAND (L,A,1000)
      I0=1
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                    SUBROUTINE SAND                        C
C    THIS SUBROUTINE CALLS AND STORES 1000 NORMALLY         C
C    DISTRIBUTED RANDOM NUMBERS, COUNTS THE NUMBERS USED    C
C    AND REFILLS THE STORAGE AREA WHEN 1000 NUMBERS HAVE    C
C    BEEN CALLED                                            C
C                                                           C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      SUBROUTINE SAND (R)
      COMMON A,B,I0,I1,C,D,L
      DIMENSION A(1000), B(1000), C(12), D(12)
      R=B(I1)
      I1=I1+1
      IF (I1.GT.999) GO TO 1
      RETURN
    1 CALL SNORM (L,B,1000)
      I1=1
      RETURN
      END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C                  SUBROUTINE BASE PAY                      C
C    THIS SUBROUTINE PROVIDES BASE PAY IN ACCORDANCE WITH   C
C    THE CUMULATIVE DISTRIBUTION PROVIDED IN MATRIX C       C
C                                                           C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
```

```
      SUBROUTINE BP (Q)
      COMMON A,B,I0,I1,C,D,L
      DIMENSION A(1000), B(1000), C(12), D(12)
      CALL RAND (X)
      DO 1 K=1,12
      IF (X.GT.C(K)) GO TO 1
      M=K
      GO TO 2
    1 CONTINUE
    2 Q=D(M)
      RETURN
      END
```

LIST OF REFERENCES

Burns, D. C., Computer Simulation of Internal Controls, paper presented at Midwest Regional Conference of American Institute for Decision Sciences,5th, Minneapolis, Minnesota, 10-11 May 1974.

Conway, R. W., Johnson, B. M. and Maxwell, W. L., "Some Problems of Digital System Simulation", Management Science Journal, v.6, October 1959.

Committee on Auditing Procedures, Statement of Auditing Standards #1, American Institute of Certified Public Accountants, Inc., 1973.

Cushing, B. E., "A Mathematical Approach to the Analysis and Design of Internal Control Systems," Accounting Review, v. XLIX, No. 1, p. 24-41, January 1974.

Hoel, P. G., Introduction to Mathamatical Statistics, John Wiley & Son, New York, 1971.

Gottfried, B. S., Programming With FORTRAN IV, Quantum Publishers, New York, 1972.

Yu, S. and Neter, J., A Stochastic Model of the Internal Control System, Faculty Working Papers, College of Commerce and Business Administration, University of Illinois, Urbana-Champaign, 17 April, 1973.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Asst. Professor David C. Burns, Code 55 Bu Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	3
4.	Lt. Col. Russell E. Jamison, USMC Code 55 Jm Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
5.	Library, Code 55 Department of Operations Research and Administrative Sciences Naval Postgraduate School Monterey, California 93940	1
6.	Lcdr. E. L. Allen 1535 Grand Teton Court Chula Vista, California 92011	1
7.	Cdr. W. E. Lowery 101 Fircrest Place Port Orchard, Washington 98366	1

Thesis
L867
c.1
Lowery
Computer simulation
as an auditing tool.
152586
28 APR 86
31018

Thesis
L867
c.1
Lowery
Computer simulation
as an auditing tool.
152586

thesL867
Computer simulation as an auditing tool
3 2768 002 12693 0
DUDLEY KNOX LIBRARY